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Experiments with Micro-elements for the Growth of Crops in Western Australia.

II. EXPERIMENTS ON HIGH LEVEL SANDY AND GRAVELLY COUNTRY IN THE SOUTHERN WHEAT BELT.

By A. S. Wild and L. J. H. Teakle.

SUMMARY AND CONCLUSIONS.

1. Experiments at Dumbleyung and Jilakin are described showing the benefit of using bluestone (copper sulphate) at the rate of 10 lbs. per acre in addition to superphosphate for wheat crops on types of high level gravelly soils.

2. At Dumbleyung potash and nitrate of soda appeared to benefit the crop, but at Jilakin the potash appeared to depress the growth. Neither manganese nor sulphate of iron proved of any benefit at either farm.

3. The experiment carried out at Dumbleyung in 1939 showed a decreased wheat yield where manganese sulphate was used. A further yield depression occurred where manganese sulphate and sulphate of ammonia were used together. The reason for this yield depression is obscure. In this instance copper appeared to have no effect but was used in combination with the manganese sulphate.

4. With Bencubbin wheat, dummy heads, purplish discoloration of straw and sheaths and a marked tendency to form secondary green tillers when the main plant is maturing are characteristic symptoms on copper deficient land.

5. Farmers desiring to experiment with these types of land are advised to apply strips of a bluestone-superphosphate mixture across the area and compare the growth with adjacent strips receiving superphosphate only. The bluestone should be applied at the rate of about 5 lbs. per acre.

I. INTRODUCTION.

Experiments carried out by one of the authors (A.S.W.) on a farm at Kukerin in 1938 and 1939 gave further proof of the value of manganese sulphate for certain classes of sandy and gravelly soils. These soils exhibit a characteristic ashy or powdery structure immediately below the surface and the cereal crops

show symptoms typical of manganese deficiency. A soil type commonly associated with manganese deficiency has been described (Teakle and Wild, 1940*) as the Tinkurrin gravelly sand. Another experiment at Wagin (Stewart and Teakle, 1939†) showed the value of copper-containing fertiliser on certain types of gravelly sandy soil.

Following the publication of the preliminary results of this work, Mr. J. W. McIntyre requested that a similar fertiliser trial be conducted on sandy and gravelly soils on his property about 10 miles north-east of Dumbleyung with a view to improving the returns which had been far from satisfactory. The soils in question were sandy and gravelly in nature but were not of the Tinkurrin gravelly sand type as the ashy subsurface soil was missing.

Collateral with the 1940 experiment on Mr. McIntyre's property, a similar arrangement of treatments was used on more or less similar land on Messrs. A. P. Carmody and Sons' property, Jilakin, East Kulin.

The seasonal conditions in 1939 were satisfactory but drought conditions prevailed throughout 1940. Rainfall records for Dumbleyung, 1939 and 1940, and for Mitchelldale—some nine miles east of Kulin and six miles west of Carmodys' property—1940, as supplied by the Commonwealth Divisional Meteorologist are as follows:

Year.	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Dumbleyung—													
1939	224	191	3	25	341	270	489	282	53	205	105	4	2,192
1940	18	5	2	25	60	150	194	173	113	65	22	166	993
Mitchelldale (9 miles East of Kulin)—													
1940	90	12	11	*Nil*	92	140	191	55	64	131	36	312	1,134

II. EXPERIMENTS ON MR. J. W. McINTYRE'S PROPERTY, DUMBLEYUNG.

Experiments were conducted on well prepared, fallowed land in 1939 and 1940.

(*a*) 1939 *Experiments.*

The soil of the area selected for the experiment may be described as ranging from a greyish yellow gravelly sand to a sandy gravel. It is located on high level areas of gently undulating topography and, in the virgin state, had carried mallee (*Eucalyptus spp.*) and various other species of scrub. No characteristic manganese symptoms had been observed in the previous crops.

Bencubbin wheat at the rate of 45 lbs. per acre and fertiliser mixtures including manganese sulphate, sulphate of ammonia and bluestone (copper sulphate) were sown with a combine cultivator drill on April 12th, 1939. Following rain on May 6th the wheat germinated evenly but sparsely. Early growth was very poor and the crop appeared virtually a failure until late in the season when some recovery was made and harvestable yields obtained. Sulphate of ammonia appeared to increase the stooling of the wheat and improve the colour, but the

* Jour. Agric., West Aust., 1940, 17: 223-233.

†Jour. Agric., West Aust., 1939, 16: 135-143.

yield was no better than the control with superphosphate alone. Manganese sulphate depressed the yield and manganese sulphate in combination with sulphate of ammonia practically reduced the yield to half the controls. Just what indirect factors are operating in this yield reduction is unknown. Mr. McIntyre, who constantly observed the growth of the crop, suggests that it is possible that the plots receiving special treatments were more advanced than the control and suffered more from the severe dry period in September. The harvester yields from the treatments used are given in Table 1.

Table 1.

YIELD OF WHEAT UNDER VARIOUS FERTILISER TREATMENTS ON MR. J. W. McINTYRE'S PROPERTY, DUMBLEYUNG, 1939.

Variety—Bencubbin. Sown—12th April, 1939. Rate of Seeding—45 lbs. per acre. Harvested—11th December, 1939.

No.	Fertiliser Treatment.		Yields.			Percentage of Control.
			Block 1.	Block 2.	Average.	
		lbs. per acre.	bush. per acre.	bush. per acre.	bush. per acre.	
1	Control—superphosphate...	150	10·3	10·5	10·4	100
2	Superphosphate	150	8·2	7·2	7·7	74
	Manganese sulphate ...	14				
3	Superphosphate	150	9·7	9·8	9·8	94
	Sulphate of ammonia ...	112				
4	Superphosphate	150	5·9	5·6	5·7	55
	Sulphate of ammonia ...	112				
	Manganese sulphate ...	14				
5	Superphosphate	150	9·0	7·3	8·1	78
	Manganese sulphate ...	14				
	Bluestone (copper sulphate)	14				

(b) 1940 *Experiments.*

The unexpected and unsatisfactory results of the 1939 experiments led to another experiment involving other treatments being laid down in 1940. In this case a physiologically alkaline nitrogenous fertiliser, sodium nitrate, sulphate of potash, and ferrous sulphate were used in the experiment. The land had been similarly prepared and was sown with Bencubbin wheat at the rate of 50 lbs. per acre on May 10th, 1940, with a combine cultivator-drill.

The soil in this case was similar to that under the 1939 experiment but overlay a clay subsoil. The area had been cleared and under cultivation for a period of nine years.

One of the worst droughts in the agricultural history of the district prevailed during the season. Mr. McIntyre registered 392 points of rain in his private gauge during the growing season (May to October). Apart from 63 points on June 18th, 73 points on July 2nd and 41 points on July 26th, the daily falls were under 20 points and usually accompanied by heavy winds.

Germination was only fair over the plots and subsequent growth was severely affected by the adverse moisture conditions. In spite of this the grain harvested from all plots was plump and well developed. All plots except those receiving

bluestone were heavily affected with dummy heads and the above ground portions showed certain of the characteristics of plants with root rot. This disease, however, was of little or no importance in this instance.

Observations made on November 12th, 1940, showed that the copper treated plots were consistently superior to all others. All plots receiving no copper carried a large proportion of dummy heads and purplish discoloration of the straw and leaf sheaths was common. It was noted that the dummy heads were generally pale yellow in colour. As compared with the superphosphate only plots, those receiving potash and potash plus manganese in addition showed more green heads and were generally less mature. Nitrate of soda plots were of somewhat improved appearance but, in some patches, the crop was less mature. Sulphate of iron had little consistent effect. By contrast, the copper treated plots were more uniformly mature than the superphosphate only plots, taller, showed few dummy heads, and most of the ears seemed well formed and well filled and characteristically bent over on the stalks.

Yield data are given in Table 2.

TABLE 2.

YIELD OF WHEAT UNDER VARIOUS FERTILISER TREATMENTS ON MR. J. W. McINTYRE'S PROPERTY, DUMBLEYUNG, 1940.

Variety—Bencubbin. Sown—10th May, 1940. Rate of Seeding—50 lbs. per acre.
Harvested—8th December, 1940.

No.	Fertiliser Treatment.		Yields.			Percentage of Control.
			Block 1.	Block 2.	Average.	
		lbs. per acre.	bush. per acre.	bush. per acre.	bush. per acre.	
1	Control—superphosphate...	112	(a) 2·7 (b) 3·1	(a) 3·2 (b) 3·0	3·0	100
2	Superphosphate ... ... Sulphate of potash ...	112 56	4·9	4·9	4·9	160
3	Superphosphate ... ... Sulphate of potash ... Manganese sulphate ...	112 56 14	4·3	4·1	4·2	140
4	Superphosphate ... ... Sulphate of potash ... Sulphate of iron	112 56 20	3·5	3·7	3·6	120
5	Superphosphate ... ... Sulphate of potash ... Nitrate of soda	112 56 112	6·3	6·5	6·4	210
6	Superphosphate ... ... Sulphate of potash ... Bluestone (copper sulphate)	112 56 10	8·3	8·1	8·2	270

Under the drought conditions prevailing these yields seem very creditable. Potash and nitrate of soda have given substantial yield increases but the effect of the copper has been spectacular and would be highly profitable—particularly as lighter dressings would undoubtedly be effective and the effect would last for more than one season. Manganese sulphate and ferrous sulphate were without beneficial effect.

It was interesting that the bulk crop, sown with only superphosphate around the experimental area at a later date, appeared to be filling reasonably well and the dummy heads were not prevalent. The purplish discoloration of the straw and leaf sheaths was present but less general than on the plots. The variety was not Bencubbin and it is possible that varietal susceptibility to copper deficiency varies and that deficiency symptoms differ.

III. EXPERIMENT ON MESSRS. A. P. CARMODY & SONS' PROPERTY, LOC. 18483, JILAKIN, EAST KULIN.

In 1936 Messrs. A. P. Carmody & Sons cleared on loc. 18483 several hundred acres of medium and light land of which over 200 acres may be described as of the wodjil type. The principal elements of the wodjil vegetation were a green leafed wodjil (*Acacia signata* or possibly *A. acuminata*—none of these plants were in flower at the time of visiting), *Hakea multilineata,* and *Casuarina acutivalvis* with a variety of shrubs including *Dampiera eriocephala, D. Wellsiana, Loudonia Roei, Leptospermum erubescens,* cauliflower bush (*Verticordia Brownii*), heath (*Micromyrtus Erichsenii*) and *Cyanostegia lanceolata.* Mallees occurred scattered through the wodjil scrub and in patches. Species identified included *Eucalyptus leptophylla* and *E. foecunda.*

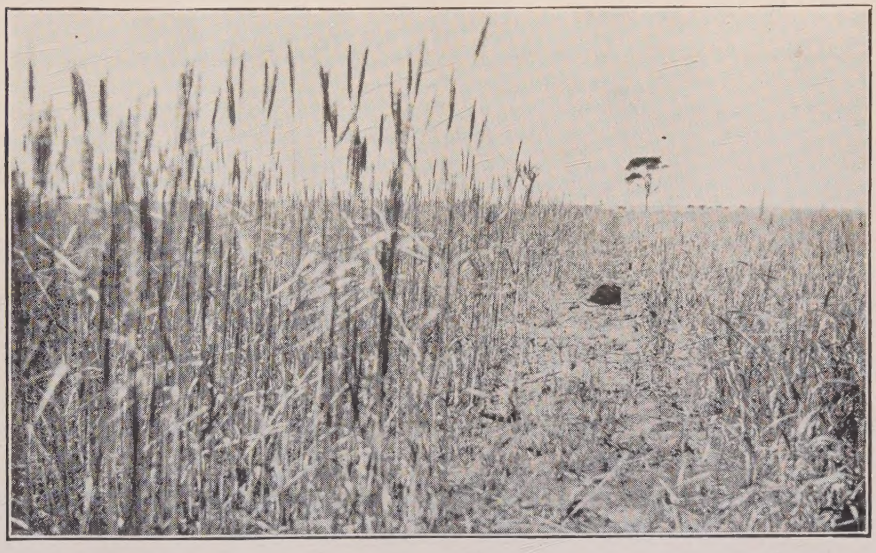

Figure 1.—Effect of bluestone on the growth of wheat on wodjil country on Messrs. A. P. Carmody & Sons, Jilakin, East Kulin, October, 1940.
Left: Plot treated with superphosphate, sulphate of potash and bluestone.
Right: Plot treated with superphosphate and sulphate of potash.
[Photo: J. Carmody.]

The area cropped in 1936 was put in very roughly and failed completely. After a two years' break crop was again sown in 1939 but the failure was almost as complete as in 1936. In an endeavour to discover the cause of the failure an experiment similar to that on J. W. McIntyre's property, 1940, was laid down on a selected site in the area where the crop had failed. An inspection was made on November 13th, 1940, and showed that the only plots on which general maturation of the wheat (Bencubbin) had occurred were those treated with copper. Harvester yields were impossible as the crop had been severely damaged by hail, but

it had been estimated that the plots treated with copper would have yielded about three bags per acre. The grain on the other plots was practically nil. Fig. 1 shows the growth, before the hail storm, on a copper treated plot in contrast with a plot receiving superphosphate and potash.

Outside the boundary of the experimental block the soil was almost completely bare. Clearing and application of superphosphate for two seasons had failed to promote an establishment of volunteer pasture plants such as cape weed, silver grass, flat weed, etc., and the chief plants growing were a number of native shrubs sparsely scattered over the area.

Examination of the wheat plants of the experimental block showed that on the control plots (superphosphate only) growth was very poor. Most of the plants had headed but practically no grain had been produced. Generally the leaves were tipped and many were dead. There was a general lack of normal stem elongation and a tendency for the leaves to bend acutely downwards from the sheath giving the shape of a conifer. A purplish discoloration of the straw and sheaths was usual as, also, were green bases showing a tendency to throw fresh tillers.

Where potash had been used growth appeared to have been depressed somewhat and there were less heads and more dead plants than on the superphosphate controls. Nitrate of soda, manganese sulphate and ferrous sulphate failed to effect any improvement.

At the time of this inspection the soils of the unsatisfactory area were examined. Two main types were recognised, (a) a brownish yellow gravelly sand to a depth of about six inches resting on a brownish yellow very gravelly sand which continues to a depth of more than 40 inches. Red gravel is common in the layers below one foot. (b) A similar surface but with a hardpan of ferruginous gravel at a depth of from one to two feet.

ACKNOWLEDGMENT.

The thanks of the authors are tendered to Mr. J. W. McIntyre and to Mr. A. P. Carmody and his sons for collaboration in these experiments and making available plant for cultural and harvesting operations.

III. EXPERIMENTS WITH POTATOES, VEGETABLES AND OTHER CROPS IN THE ALBANY DISTRICT.

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Summary.

1. Details are given of the results of a number of experiments arranged to determine the response of a variety of crops to various micro-elements used in addition to the usual basal fertilisers.

2. The crops used included potatoes, tomatoes, peas, maize, swedes and onions. Copper, manganese and zinc sulphates were tested in most experiments but boron and magnesium were used in three instances.

3. No response in yield was obtained from any micro-element or combination of micro-elements on Grasmere or Many Peaks.

4. On the neutral, sandy swamp soils of Lake Saidie and the acidic bottlebrush country at Torbay, copper appears to be the primary deficiency and no improvement has been observed where other micro-elements have been added. Potatoes, tomatoes and maize crops gave excellent responses to bluestone used at the rate of 5 to 10 lbs. per acre under these conditions. Heavier applications produced similar yields.

5. On Lake Saidie, land which had deteriorated under previous crops gave the greatest response, but new land was also improved by the use of bluestone. There seemed to be no difference between row and broadcast methods of application of the bluestone.

6. There was an indication that some advantage followed the use of a small dressing of bluestone in years succeeding the initial application.

7. On the marly soils of Little Grove, both copper and manganese are of importance and interesting differences in crop responses were observed.

8. For tomatoes, copper was of prime importance on the marly soils and copper-containing fertilisers produced satisfactory yields of excellent fruit. The addition of manganese to the copper-containing fertiliser may have improved the production of fruit but the differences were not conclusive.

9. On the marly soil, for peas and swedes, copper was also of prime importance but further substantial improvement in yield was observed when manganese was used in addition to the copper. On this soil, in the absence of copper, peas produced either small, abortive pods or large pods containing tiny, abortive seeds.

10. Potatoes on the marly soil failed to grow normally without manganese in the fertiliser mixture. With manganese good yields of excellent tubers were obtained. The addition of copper to the manganese-containing fertiliser further increased the yield. Copper without manganese was not effective. The results indicate that 10 lbs. of manganese sulphate plus 5 lbs. of bluestone per acre should be used for potatoes on this soil.

11. The use of zinc did not increase yields but appeared to hasten the maturity of peas and swedes.

12. Chemical data are given with respect to certain of the experimental crops.

I. INTRODUCTION.

A brief review of the position with respect to the value of micro-elements for the growth of crops on certain soils of Western Australia has been published in this Journal (Teakle, 1939) and need not be repeated. An error in this review, arising from a misunderstanding, may be corrected. Further inquiry showed that the Young Bros. at Young's Siding had not used bluestone as a fertiliser until recent years, but had used bluestone solution as a spray for the control of potato blight some 22 years ago; the potatoes were killed as a result of the spraying, but the succeeding crop of onions was observed to be exceptionally good.

Following this review, details of exploratory tests and experiments with potatoes, vegetables, pastures and cereals were given. These showed outstanding effects under certain conditions and form the background for the series of experiments discussed below. This series of experiments included potatoes, tomatoes, peas, onions, swedes and maize in the Albany district.

Of course, all experiments have not yielded positive or spectacular responses. On a number of sites used in the course of the experimentation satisfactory crops have been produced without special application of micro-elements with the usual fertiliser. It is not to be expected that our agricultural land is generally deficient, at least not acutely deficient, in micro-elements; in fact, large areas are known to be sound for crop and animal production, but there are considerable areas of country in the settled districts which are not entirely satisfactory under agricultural development and apparently some of these soils will benefit from the use of special fertilisers in addition to the usual superphosphate. The experiments here reported represent another step in the direction of the determination of the soil types requiring such special treatments. They were also designed to point to the most economical rates and combinations of micro-elements for the respective crops on the range of soils under examination.

The 1939-40 summer season proved extremely dry and little beneficial rain fell during the growing period. This has probably affected the growth and quality of the potatoes in some instances and materially interfered with the growth of maize. Rainfall records for three centres representative of the experimental areas are given in Table 1.

TABLE 1.

RAINFALL RECORDS FOR CENTRES REPRESENTING AREAS ON WHICH EXPERIMENTS HERE DISCUSSED WERE CARRIED OUT.

(Information kindly supplied by the Commonwealth Divisional Meteorologist.)

—	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Denmark—													
1939	710	56	67	196	512	555	487	1,003	116	541	251	41	4,535
1940	111	39	42	184	534	314	448	314	375	237	165	236	2,999
Av., 38 years to 1939	128	138	215	324	573	686	739	660	508	440	183	140	4,734
Albany—													
1939	854	78	111	402	473	522	429	863	165	460	350	15	4,722
1940	96	54	27	148	436	311	445	312	361	152	103	157	2,602
Av., 63 years to 1939	101	89	160	277	506	549	560	536	409	328	147	116	3,778
Many Peaks—													
1939	648	106	69	157	344	341	324	519	123	523	247	31	3,432
1940	77	15	7	139	....	300	362	182	262	105	143	223	....
Av., 5 years to 1939	209	59	157	197	421	389	448	432	271	277	135	105	3,100

Rainfall recorded during Growing Months of December, January, February, and March.	1939–40.	Average for period of records.
	points.	points.
Denmark	233	621
Albany	192	466
Many Peaks	130	530

The lateness of the spring rains in 1939 interfered with cultural operations on Mr. B. H. Burvill's property, Grasmere, but conditions at planting in November, 1939, were reasonably satisfactory. On Mr. J. Poole's property, Grasmere, planting was postponed until December.

II. EXPERIMENTS WITH POTATOES IN THE ALBANY DISTRICT.

Experiments with Delaware potatoes were carried out on summer land at Grasmere, Many Peaks, Little Grove and Lake Saidie. Lake Saidie represents an area acutely deficient in copper, Little Grove is acutely deficient in manganese and copper, Grasmere has produced splendid crops of potatoes practically every year for over 40 years without special fertiliser treatments, and Many Peaks represents virgin peat land.

In the course of this work a complex form of experimental technique known as the factorial design was adopted in four instances, and a more simple randomised block used for collateral purposes. The factorial design involves the use of all possible combinations of fertiliser and the rates of application under test. Bluestone, manganese sulphate and zinc sulphate were the fertilisers under test and each was applied at four different rates. Thus bluestone and manganese sulphate were each applied at the rates of nil, 5 lbs., 10 lbs., and 20 lbs. per acre, and the zinc sulphate at nil, 2½ lbs., 5 lbs., and 10 lbs. per acre. To cover all possible combinations 4 x 4 x 4 = 64 treatments were required and constituted one block. The treatments were triplicated, to provide for adequate replication, so that each experiment involved three blocks totalling 192 separate plots.

Except where special "seed" was used, experimental areas were planted with "seed" from light soil which would not be expected to build up much reserve in the tubers. By this means it was hoped to obtain maximum responses from the special fertiliser treatments.

When dug, the tubers were classified primarily into first grade and rejects and weighed as such. Study of the yield data indicated that the total yield could be used most conveniently to express the effect of the treatment. Except at Little Grove, fertiliser treatment had little effect on the percentage of first grade tubers so that the total yields accurately reflect the treatment responses. The disadvantage of this method of expression is the fact that the yield data reported are in excess of normal commercial figures. However, the figures are strictly comparable and, if desired, the yield of first grade tubers can be estimated from the data in the tables.

A. *Experiments at Grasmere.*

The Grasmere area consists of valuable swamp land which has produced consistently heavy crops of potatoes for over 40 years. The soils are peculiar in that the mineral fraction consists largely of an assemblage of diatomaceous and spicular remains impregnated with a small amount of organic matter. This formation extends to a depth of two to four feet or more and rests on a sandy bottom. The soils are light grey in colour, highly porous, light in weight and absorbent when dry. The reaction normally appears to be moderately acid (pH 5 to 6) but may be strongly acid in parts (pH 4 to 5). Salinity is not high. Two factorial experiments and two randomised block experiments were laid down, one of each pair being on Mr. B. H. Burvill's property, Location 3103, and the other on Mr. J. Poole's property, Location 2734. On Mr. Burvill's property, the basal fertiliser used was potato manure H* at the rate of 12 cwts. per acre and on Mr. J. Poole's, potato manure B* at the same rate.

The yield data for the factorial and randomised block experiments are given in Table 2.

* For the composition of the potato manures see the appendix.

TABLE 2.

RESULTS OF APPLICATION OF FERTILISERS CONTAINING MICRO-ELEMENTS ON GRASMERE SOILS UNDER POTATOES.

B. H. Burvill, loc. 3103.—Planted 22nd November, 1939 ; dug 12th–14th March, 1940 ; basal fertiliser, potato manure H (12 cwts. per acre).

J. Poole, loc. 2734.—Planted 13th December, 1939 ; dug 17th–19th April, 1940 ; basal fertiliser, potato manure B (12 cwts. per acre).

	Yield (tons per acre).	
	B. H. Burvill.	J. Poole.
(*a*) *Factorial Experiment.*—Bluestone and manganese sulphate used at *nil*, 5 lbs., 10 lbs., and 20 lbs. per acre ; zinc sulphate at *nil*, 2½ lbs., 5 lbs., and 10 lbs. per acre—		
Average yield of experimental area	9·7	14·8
Proportion of first grade tubers	85%	86%
Examination of the yield data shows that there is no statistically significant effect from any combination of the micro-elements.		
(*b*) *Randomised Block Experiment*—		

No.	Fertiliser treatment.	Rate per acre.		
1	Control—potato manure	12 cwts.	8·5	11·6
2	Control plus bluestone	10 lbs.	9·0	12·0
3	Control plus manganese sulphate	10 lbs.	8·6	12·9
4	Control plus zinc sulphate	5 lbs.	8·4	11·8
5	Control plus borax	5 lbs.	9·1	11·8
6	Control plus magnesium sulphate	20 lbs.	8·4	12·0
7	Control plus magnesium sulphate	100 lbs.	9·1	12·5
	Proportion of first grade tubers	...	83%	86%
	Differences not significant at P=·05.			

As statistical analysis of the data from the factorial experiments showed no effect from the variations in treatment, only the average yield over the whole experiment is given in each case. With respect to the randomised block experiments, yields from each treatment are reported. Again, statistical analysis of the data shows that the differences are not significant at P = .05* and it must be concluded that the use of micro-elements is probably not warranted on this type of country. Certainly the excellent yields which have been maintained over a long period of years are not suggestive of nutritional deficiencies.

During the growth, no foliage differences could be observed on Mr. Burvill's property but on Mr. Poole's the plots receiving no manganese could be distinguished by a bronzy yellow tinge on the foliage when examined on January 18th, 1940, about six weeks after planting. This symptom appeared to persist only over a short period and was not apparent when the crop was more mature. As the

* In the examination of such experimental results it is first necessary to decide whether the yield differences between plots or treatments are due to chance variations, such as soil changes, incidence of disease, etc., or to the actual treatments. If the experiment has been properly designed the probability that the treatment has caused the yield differences can be determined mathematically. When the difference between treatments is stated to be significant at P = .05 it means that there are at least 19 chances in 20 that the effect is due to the treatment and not to chance variations. In these experiments the differences are deemed to be due to the treatment if they pass the test for significance at P = .05.

manganese treated plots have given slightly higher yields in the randomised block experiment, it is possible that the difference is not due to chance and some benefit from the inclusion of manganese in the fertiliser mixture may be obtained on that portion of the Grasmere swamp represented by Mr. Poole's experiment.

B. *Many Peaks Experiment.*

The factorial design was adopted to determine the effect of combinations of micro-elements on virgin peat marsh land at Many Peaks. The area selected was a strip of about 2½ chains wide lying between the bank or shore of the peat formation and the central lagoon.

The surface peat is blackish brown to brownish black in colour and fibrous in nature. It rests on a subsurface of well-decomposed material black in colour and more of the consistency of a muck. Below this, the deeper layers are brown in colour and of a soft fibrous nature. At the site of the plots, the peaty layer was generally more than six feet deep but shallower parts to occur. At some sites, a pale greenish sandy clay bottom has been observed within a few feet of the surface and at certain places bars of gravelly clay at shallow depths in the peat act as dams and restrict drainage. Analysis shows the peat to be strongly acidic (approximately pH 4) and low in mineral matter. Some concentration of water soluble sulphates has occurred.

In preparation for planting, the bulrushes were cut and burnt and the land cultivated once with a rotary hoe which opened out a planting furrow. The "seed" and fertilisers were dropped in the furrow and covered by hand.

At the time of planting, the soil was wet and soggy at a depth of eight to nine inches but rapid drying out took place during the dry summer period. As a result the subsurface peat cracked badly and large crevices, two to three feet deep, opened up, particularly along the lines sown to potatoes. In consequence, harvesting by means of forks was impossible and had to be effected by scraping away the surface peat by hand and picking the potatoes from the subsurface and the crevices. Some of the tubers dangling in the crevices had been chewed by mice, but little material damage was done and potatoes of excellent eating quality were harvested.

During growth, no consistent differences were noted; the foliage was not heavy but was healthy and normal. When dug it was observed that a considerable portion of the tubers on the dry soil nearer the bank were large and knobby and irregular in shape due to secondary growth. There appeared to be no relation between treatment and tuber shape and it seemed that seasonal and soil conditions were of principal importance in causing this effect. The block on the more moist portion of the experimental area nearest the lagoon carried very attractive foliage but yielded less; further, the tubers were more generally of good shape, if somewhat smaller in size, than on the drier land. On this block a little stem end rot occurred; this occurrence was without any apparent relation to fertiliser treatment. Yield data are given in table 3.

Accepted on their face value, the figures indicate a slight depression in yield where manganese was used and a slight improvement where bluestone was applied. The variability was such, however, that the significance of the responses must be accepted with caution—but they indicate the possibility of a beneficial response to copper fertilisers as the cropping programme is continued.

C. *Little Grove Experiments.*

The advantage of using manganese for potatoes on Mr. B. H. Burvill's property, Little Grove, has been reported by Teakle and Morgan (1939). To obtain further evidence regarding the best combination of micro-elements on this marly

marsh soil a factorial experiment was laid down. Again the deficiency of manganese was evident from the very unthrifty growth of the tops, the bronzy yellow colour of the leaves, and a common tendency to leaf scorch. The results of the statistical analysis of the yield data are summarised in Table 3.

TABLE 3.

YIELDS OF POTATOES FROM FACTORIAL EXPERIMENTS WITH MICRO-ELEMENTS AT MANY PEAKS, LITTLE GROVE, AND LAKE SAIDIE.

B. H. Burvill, Many Peaks.—Planted 29th–30th November, 1939 ; dug 21st–27th March, 1940 ; basal fertiliser, potato manure E (12 cwts. per acre).

B. H. Burvill, Little Grove.—Planted 16th and 17th November, 1939 ; dug 2nd–5th April, 1940 ; basal fertiliser, potato manure H (12 cwts. per acre).

J. C. Blake, Lake Saidie.—Planted 24th and 25th October, 1939 ; dug 26th February–1st March, 1940 ; basal fertiliser, potato manure G (12 cwts. per acre).

No.	Special fertiliser.	Rate per acre.	Yield (tons per acre).		Little Grove.	
			Many Peaks.	Lake Saidie.	Yield.	Per cent. first grade.
		lb.			tons per acre.	
1	Manganese sulphate level (with all combinations of other micro-elements)	*nil*	11·7	13·2	6·7	45·9
		5	11·4	13·9	10·3	57·2
		10	11·0	13·9	12·7	62·4
		20	11·2	14·0	13·4	61·4
2	Bluestone level	*nil*	11·0	9·6	9·5	56·3
		5	11·4	14·5	11·5	56·3
		10	11·5	15·2	11·0	58·3
		20	11·4	15·7	11·0	55·9
3	Zinc sulphate level	*nil*	11·3	14·2	11·1	53·8
		2½	11·2	13·3	10·7	56·2
		5	11·2	14·1	10·7	59·1
		10	11·6	13·4	10·6	57·7
	Difference for significance, P=.05 ...	...	0·4	*	0·97	...
	Proportion of first grade tubers ...	...	66%	92%	59%	...

* Symmetry of experiment destroyed by previous application of copper and manganese to portion of the experimental area.

It will be noted that improved yields were obtained from the use of manganese and of copper. Table 4 shows that the benefit from copper occurred only when manganese also was used in the mixture and indicates that the most economical combination for potatoes on this land was 10 lbs. of manganese sulphate and 5 lbs. of bluestone per acre along with the potato manure. During the growing period it was noted that the higher rates of bluestone, when used without manganese or with low dressings of manganese, tended to accentuate the foliar symptoms of manganese deficiency. The yields failed to show any substantial depressing effect but the figures from Table 4 may be taken to indicate a tendency for lower yields to be harvested when 20 lbs. of bluestone per acre were applied

in the presence of only 5 lbs. of manganese sulphate per acre. Zinc was without effect on the yield. Figures in table 3 show that the percentage of first grade tubers in the crop was increased about 30 per cent. where manganese was applied. No effect was observed with the other treatments.

Table 4.

THE INTERACTION OF BLUESTONE AND MANGANESE SULPHATES WHEN USED AS FERTILISERS FOR POTATOES ON MARLY MARSH LAND, LITTLE GROVE, ALBANY.

Yields of Potatoes in tons per acre under each treatment.

Manganese Sulphate. (lbs. per acre).	Bluestone (lbs. per acre).			
	0.	5.	10.	20.
0	7·2	6·3	6·3	7·0
5	10·3	11·2	10·2	9·3
10	10·4	14·1	13·3	13·1
20	10·1	14·4	14·4	14·6

Fig. 1.—Effect of manganese sulphate on the development of potato tubers on marl at Little Grove.

Top Row: Tubers from plot receiving no manganese.

Bottom Row: Tubers from plot receiving manganese.

The largest tubers from each plot were selected for the photograph. The scale is 12 inches long. Potatoes dug April 7th, 1940.

The tubers from the plots receiving manganese were generally large and many weighed over 28 ounces each when dug. Furthermore the potatoes proved of excellent cooking and keeping quality. Figure 1 illustrates the type of the larger tubers dug from these plots.

D. *Lake Saidie Experiments.*

Lake Saidie represents a considerable area of valuable swamp land about three miles south of Young's Siding and 20 miles west of Albany. The actual swamp land occurs as winding strips and lenses separated by low sandhills formed of material blown in from the coast. Some of this material is calcareous with the result that patches of marl occur on portion of the swamp and complicate the nutritional problems.

The portion of the swamp under experimentation carried, in the virgin state, swamp karri, watties (*Agonis juniperina*), paperbark, sword grass (*Lepidospermum gladiatum*) and other rushes and scrub. The soil is generally sandy and may be described as a dark grey to greyish black organic sandy loam merging into grey sand or yellow sand at a depth of about 18 inches. Patches of poor grey sand occur and a dark grey to yellowish olive sandy clay hardpan has formed at a depth of six to 12 inches on other patches where paperbark occurs. The salt content is low (.02 per cent.) and the reaction about neutral (pH 6.6 to 7.2); lime nodules may occur in the deeper subsoil.

Reference has already been made to the spectacular responses of cabbages and potatoes to bluestone dressings on this type of swamp on Mr. E. Cake's property (Teakle and Morgan (1939), page 125).

Mr. K. E. Martin and Mr. J. C. Blake reported similar results and arrangements were made to obtain more precise information on their properties.

1. *Mr. J. C. Blake's property.*

This property lies a few chains west of Mr. K. E. Martin's and represents very similar soil conditions. With respect to the cropping history of the areas selected for the experimentation, 1½ lands on the north had been under potatoes for the seven years 1930-1936 inclusive and under maize in 1937 and in 1938. The maize had been fertilised with copper and manganese sulphates each at the rate of 20 lbs. per acre but this fact was not reported when the experiment was laid down. The rest of the area (4½ lands) had been under *Lotus major* during the last four to five years but had previously been cropped to potatoes.

The experiment was designed on the factorial plan and was similar to those at Grasmere, Little Grove and Many Peaks except that space only permitted duplication of the blocks. A small collateral experiment involving the use of boron and magnesium, in addition to the copper, manganese and zinc, was also carried out. In this experiment the basal fertiliser was potato manure G* applied at the rate of 12 cwts. per acre.

In this experiment buffer rows between the treatments were not used as observations made previously had indicated little or no side effect. The soundness of this action was checked by comparing the yields of crown and furrow buffers adjacent to rows with and without copper. The results were as follows:

Buffer.	Yield of Tubers. Adjacent Rows received—	
	Bluestone.	No Bluestone.
	tons per acre.	tons per acre.
Crown buffers	4·7	5·0
Furrow buffers	5·8	6·1

* For the composition of the potato manures used see the appendix.

These figures indicate no positive side effect in this experiment.

An experiment carried out on similar land on Mr. K. E. Martin's property nearby to determine the side effect more accurately, gave the following results:

1. Rows receiving bluestone—18.5 tons per acre.
2. Adjacent rows with no bluestone—6.3 tons per acre.
3. Second rows with no bluestone—4.3 tons per acre.

From this evidence it is concluded that there may be a very slight lateral effect, but this effect would not interfere in the experiment.

Except on the area previously dressed with copper, the plots receiving bluestone stood out throughout the growing period and the plants were superior in colour and growth. No differences were observed on the portion of the area which had received bluestone and manganese with the previous maize crops.

In consequence of the previous copper treatment on the northern 1½ lands, the symmetry of the design was destroyed and statistical treatment rendered impossible. However, an attempt was made to estimate treatment effects by calculating the yields of plots receiving each level of micro-element fertiliser within the area not previously treated with copper. As the collateral treatments in each group will not be identical, small differences must be overlooked. The fact that neither manganese nor zinc appear to have had any effect on the yield enables the figures to reflect the effect of the use of copper as a fertiliser. The results are given in Table 3. These figures show that there is no effect on the yield when manganese and zinc are not included in the mixture. When copper is omitted, however, the yield drops from 15 tons per acre to less than 10 tons per acre. It appears that neither manganese nor zinc fertilisers are necessary for the growth of potatoes on this type of land. In the collateral experiment magnesium sulphate at the rate of 20 lbs. per acre had no effect on the yield.

It should be remarked, however, that, where marly patches occur in the Lake Saidie swamp soils, manganese deficiency is likely to be a factor and there is evidence from Mr. E. Smith's experience that both copper and manganese in combination should be used on such patches.

The tubers from the experimental area appeared to be of good quality and cooked nicely when freshly dug. The percentage of first grade tubers was exceptionally high.

2. *Mr. K. E. Martin's property, location* 3716.

The land selected for the experiment was typical of the area as described above. It had been cleared in 1934 of the cover of swamp karri, sword grass, etc., and had given the following returns:

1934 Delaware potatoes—10 tons per acre.
1935 Bismarck potatoes—14 tons per acre.
1936 Delaware potatoes—1½ tons per acre.
1937-38 Under *Lotus major*.
1939 Fallowed in the autumn.

The area was subdivided into 25 plots on the latin square principle and the following fertiliser treatments applied in the row with the sets:

(a) Control, potato manure G* 12 cwts. per acre.
(b) Control plus bluestone at the rate of 5 lbs. per acre.

* For the composition of the potato manures used see the appendix.

(c) Control plus bluestone at the rate of 15 lbs. per acre.

(d) Control plus bluestone at the rate of 30 lbs. per acre.

(e) Control plus a mixture of copper, manganese, zinc and boron salts.

Six types of "seed" were used on each plot. They were:

(a) "Seed" from the Benger district grown on a fertile marsh on the coastal plain about 100 miles south of Perth, and

(b) Five types of "seed" grown on karri hill land on Mr. K. E. Martin's property, Tennessee, the previous autumn with a variety of micro-element treatments. The treatments used in the production of this seed and the yields are given in Table 5.

TABLE 5.

YIELDS OF POTATOES GROWN ON K. E. MARTIN'S KARRI HILL LAND TO PRODUCE "SEED" FOR THE EXPERIMENT ON LAKE SAIDIE.

Planted 22nd February, 1939. Dug 7th–8th June, 1939.

	Fertiliser Treatment.	Rate per acre.	Yield per acre.
			tons.
A.	Control—Potato manure H*	about 15 cwt.	4·9
B.	Control plus bluestone	15 lbs.	5·6
C.	Control plus manganese sulphate ...	15 lbs.	5·3
D.	Control plus bluestone	15 lbs.	5·5
	Control plus manganese sulphate ...	15 lbs.	
E.	Control plus bluestone	15 lbs.	5·7
	Control plus manganese sulphate ...	15 lbs.	
	Control plus zinc sulphate	5 lbs.	
	Statistical examination of the results showed no response to treatment.		

Plot variation was such that these differences in yield may not be regarded as significant (Z test). Specific gravity tests indicated that the best quality tubers came from the copper (B) and copper plus manganese (D) treatments, and the poorest from the control plots (A). Cooking tests were inconclusive.

The experiment on Lake Saidie was planted under good conditions on October 20 and 21, 1939. During the growing period the rows of Benger "seed" were consistently outstanding in appearance. More rapid growth was made from the outset, the plants were more erect, better branched, and the leaves more healthy and of a light green colour associated with vigour. Little differences could be detected among the other lines of "seed."

The current fertiliser treatments showed marked effects on the growth of the foliage. All plots receiving copper carried vigorous thrifty looking plants which withstood the dry summer conditions well. The plots receiving bluestone at the rate of 5 lbs. per acre appeared somewhat inferior to the others. By contrast the controls receiving potato manure G alone, were inferior throughout the growing period; the foliage was darker green in colour, the plants were stunted in growth and were severely affected by periods of hot weather.

* For the composition of the potato manures used see the appendix.

When the crop was dug, it was found that the control plot showed a low yield of tubers. The tubers were pointed, frequently long and narrow, and sometimes crescent-shaped. A stem end break down in which the flesh turns to a soft jelly-like consistency was particularly general. This condition is referred to as "jelly-end rot." Excellent yields were obtained from the plots receiving copper, but the quality of the tubers was only fair and deterioration was severe during storage. The superiority in quality is indicated by the lower moisture content of the tubers from the copper treated plots but even these were higher in moisture content than tubers of high quality from Many Peaks (see Table 14). The yields of potatoes in this experiment are given in Table 6.

Table 6.

YIELD OF POTATOES FROM EXPERIMENT ON K. E. MARTIN'S PROPERTY, LAKE SAIDIE.

(Split plot Latin square design.)

Planted 20th–21st October, 1939. Dug 4th–6th March, 1940.

(i) Shows the yields from the five different fertiliser treatments irrespective of the source of the "seed."

(ii) Shows the yields of the six different types of "seed," each yield figure being the average of the results from the five fertiliser treatments.

No.	Fertiliser Treatment.	Rate per acre.	Yield per acre.
			tons.
	(i) Effect of fertiliser on yield.		
1	Control—Potato manure G	12 cwt.	6·9
2	Control plus bluestone	5 lbs.	16·7
3	Control plus bluestone	15 lbs.	16·8
4	Control plus bluestone	30 lbs.	17·1
5	Control plus bluestone	15 lbs.	14·2
	plus manganese sulphate	15 lbs.	
	plus zinc sulphate	5 lbs.	
	plus borax	5 lbs.	
	Difference for significance P=·05	...	1·6
	Proportion of first grade tubers—78%		
	(ii) Effect of source of "seed" and of the fertiliser treatment of the crop producing "seed" used in the experiment.		
	Fertiliser treatment of "seed" crop grown on K. E. Martin's Karri Hill Land (see Table 5)—		
1	Control—Potato manure	...	12·7
2	Potato manure plus bluestone	...	13·5
3	Potato manure plue manganese sulphate ...	...	13·1
4	Potato manure plus bluestone, manganese sulphate	...	14·5
5	Potato manure plus bluestone, manganese sulphate, zinc sulphate	...	13·6
6	"Seed" produced at Benger	...	18·7
	Difference for significance P=·05	...	1·2
	(iii) Yield of "seed" on control plots.		
1	Benger "seed" on controls	...	9·1
2	Other "seed" on controls	...	6·1

These figures show the outstanding effect of adding a small amount of copper to the ordinary potato manure for the production of potatoes on this type of land. It appears that 5 lbs. of bluestone per acre has given yields not significantly different from the higher rates, but the inclusion of manganese, zinc and boron salts has brought about a reduction. This harmful effect is probably due to boron as no reduction was noted in the 1940-41 crop when this element was omitted. Regarding the effect of the type of "seed" and the treatment of the crop producing the seed, the figures in Table 6 show that the plots sown to Benger "seed" outyielded the other plots by four or five tons per acre notwithstanding the fertiliser treatment. Of the "seed" from the karri hill soil, that from the plots receiving copper and manganese seems somewhat superior to the other treatments—certainly better than that from the control. In comparing the results from "seed" of different sources the comparison of the experimental rows with buffer rows sown with tubers from very light hill soil at Denmark is of added interest. Just as the Benger "seed" proved superior to the lines produced on Mr. Martin's karri hill land at Tennessee, so this Denmark "seed" was very much inferior to these lines. In fact, many of these buffer rows without copper carried only odd sound tubers—that is, tubers not affected by jelly-end rot or malformation—and the total yield was generally less than half that of rows of the other "seed" from the control plots. It is felt that the superiority of the Benger "seed" is of utmost importance and it is hoped that proper examination of these potatoes may give important information regarding the factors affecting quality in "seed" potatoes.

The spectacular results from this experiment made it desirable to continue to use these plots to obtain further information, particularly with respect to the residual value of the copper treatment. The layout was not suitably designed for this purpose, but indications were obtained in the 1940-41 season by modifying the plot treatments so that half of each land received the original fertiliser mixture while the other half was dressed with potato manure only. Collaterally, half of each of the control plots was used to obtain some information regarding the effect of lower rates of bluestone. One pound and 2½ pounds per acre were compared with five pounds. Of course, the modifications in the treatments render it impossible to apply the usual methods of analysis strictly to the results, but deductions of some value may be drawn from the yield data given in Tables 7 and 8. These deductions will be of value in organising future work.

TABLE 7.

EFFECT OF RETREATMENT OF PLOTS WITH BLUESTONE ON THE YIELD OF POTATOES—K. E. MARTIN, LAKE SAIDIE, 1940–41.

Planted 29th–30th October, 1940. Dug 4th, 5th and 6th March, 1941.

Basal Fertiliser—Potato manure E, 10 cwt. per acre, 1940–41.

Special Fertiliser.	Total Yield of Tubers.	
	Applied 1939–40.	Applied 1939–40 and 1940–41.
	tons per acre.	tons per acre.
Bluestone 5 lbs. per acre	13·2	14·0
Bluestone 15 lbs. per acre	12·1	13·4
Bluestone 30 lbs. per acre	13·7	13·9
Mixture*—Treatment 5, Table 6.	11·8	13·8

Plots receiving no bluestone yielded 7·4 tons per acre.

* Borax omitted 1940–41.

Table 8.

EFFECT OF RATES OF APPLICATION OF BLUESTONE ON THE YIELD OF POTATOES—K. E. MARTIN, LAKE SAIDIE, 1940–41.

Planted 29th and 30th October, 1940. Dug 4th, 5th and 6th March, 1941.

Basal Fertiliser—Potato manure E, 10 cwt. per acre.

Bluestone Application.	Total Yield of Tubers.
lbs. per acre.	tons per acre.
nil	7·4
1	10·4
2½	11·0
5	12·5
Difference necessary for significance P = ·05	1·6

The data in Table 7 indicate primarily that the previous application of bluestone had a very marked residual value in that the yield was raised from about seven tons to over 12 tons of potatoes per acre. They also indicate, in the case of the lower rates of application of bluestone (5 lbs. and 15 lbs. per acre), a slightly improved yield may be obtained when a further dressing is made with succeeding crops. Furthermore, there is no significant yield difference between the application rates of 5, 15 and 30 lbs. of bluestone per acre.

The data from the collateral experiment (Table 8) showed that 1 lb. of bluestone per acre produced a substantial improvement but was inadequate as it proved inferior to the 5 lbs. per acre rate. An intermediate yield resulted from the 2½ lbs. per acre application. It may be concluded that the observations available indicate the value of small dressings—of the order of magnitude of 5 lbs. of bluestone per acre—and that it is advisable to apply a small dressing in succeeding years for a period, at least.

But the yield data do not supply the whole story as the quality factor is important. The incidence of jelly-end rot and marked tendency to pointed tubers on the 1 lb. and 2½ lbs. of bluestone per acre rows, suggests suboptimal copper status. The 5 lb. dressing, also, failed to eliminate completely these defects.

Moisture determinations were made on samples from control rows and from rows receiving 30 lbs. of bluestone per acre in the two successive years. From the control rows the tubers contained 16.6 per cent. dry matter while from the heavy copper dressings the average was 20.7 per cent. dry matter. This indicates a great improvement in quality where copper has been used on this type of soil.

Portions of these samples were stored in the laboratory for a period of two months. The tubers kept well; those showing jelly-end rot dried nicely and showed no sign of further deterioration. The only difference noticed was the early production of strong shoots, particularly from the crown end, by the copper treated potatoes. The others had not shot in the two-month period.

In view of the reported deterioration of this land after the first two or three crops, it was desirable to obtain information under controlled conditions. Mr. Martin kindly made available an area of newly cleared land for this purpose and a latin square design was used to compare the yields from potato manure E alone (10 cwts. per acre) with yields from plots treated with bluestone in addition. The bluestone was applied both broadcast immediately prior to planting and in the row with the basal fertiliser. These plots were on the same location as the first experiment and lay about five chains to the south.

The experiment was planted on December 16th and 17th, 1940. Satisfactory growth was made throughout the growing season but maturation was hastened by March rains. Foliage differences were slight but the control plots were generally less vigorous than the others.

Although the crop was ready to harvest in the middle of April digging was delayed and was carried out on April 21st to 23rd, 1941.

Generally the tubers were of excellent shape and appeared of good quality. A certain amount of second growth occurred, particularly in patches, but apparently was not in any way related to fertiliser treatment.

Samples from each plot were taken for moisture determination with a view to obtaining some estimate of the effect of treatment on quality.

Yield data and moisture contents of tubers are given in Table 9.

TABLE 9.

YIELD OF POTATOES ON NEW LAND ON MR. K. E. MARTIN'S PROPERTY, LAKE SAIDIE.

Planted 16th and 17th December, 1940. Harvested 21st–23rd April, 1941.

"Seed"—From light forest country on Denmark Research Station.

Design of experiment—Latin square.

No.	Treatment.	Yield of Tubers.*	First Grade.‡	Moisture Content.
		tons per acre.	%	%
1	Control—Potato manure E, 10 cwt. per acre ...	9·2	91	80·6
2	Control plus 10 lbs. bluestone per acre broadcast ...	11·1	93	80·2
3	Control plus 20 lbs. bluestone per acre broadcast ...	10·5†	91	80·2
4	Control plus 10 lbs. bluestone per acre in rows ...	11·1	91	79·9
5	Control plus 20 lbs. bluestone per acre in rows ...	11·5	91	80·2
	Difference for significance P=·05	1·0		

* Includes all tubers produced. † One plot under this treatment was abnormally low, apparently on account of some localised soil condition. ‡ More than 3 ounces in weight.

These data show that a substantial increase in yield on the new land was obtained from the use of bluestone with potato manure. They also show that no advantage was obtained by increasing the rate of application of bluestone from 10 pounds to 20 pounds per acre, and, furthermore, the bluestone appeared to be just as effective when broadcast separately prior to planting as when applied in the row with other fertiliser and the "seed."

No evidence of any effect of the treatments on the quality of the tubers was obtained from observations in the field or from the moisture data. From all plots, the potatoes appeared to be of good quality.

III.—EXPERIMENTS WITH OTHER CROPS IN THE ALBANY DISTRICT.

Collateral experiments were conducted with other crops in the Albany District.

A. *Experiments with Tomatoes, Onions and Peas on Mr. T. H. Tonkin's property, Lake Sadie.*

This property lies immediately east of Mr. K. E. Martin's discussed above, and represents similar soil conditions. These conditions also prevail on Mr. J. C. Blake's and Mr. E. Cake's properties which lie to the west in the same area.

Fig. 2.—Barley plants grown with and without copper on Mr. E. Cake's property, Lake Saidie.

Left: Four plants from rows not treated with bluestone.

Right: Two plants from rows treated with bluestone at the sowing of the previous crop of cabbages.

Note the failure of the copper deficient plants to progress toward maturation, the poor root system and the stringy tips of the leaves. Photo taken June 8th, 1939.

Before discussing the results of these experiments mention may be made of the behaviour of barley on this type of land following a crop of cabbages on Mr. E. Cake's property referred to in a previous paper (Teakle and Morgan, 1939). It will be remembered that a couple of rows of cabbages were planted without bluestone and had practically failed. The barley germinated well and grew normally for a few weeks. Then the plants on the strip receiving no copper began to deteriorate and exhibited the typical symptoms of copper deficiency in cereals, whereas good growth was made elsewhere.

Deficiency symptoms exhibited by the barley plants from the rows receiving no copper are shown in Fig. 2. Healthy plants from copper treated rows are illustrated for contrast.

With the advance of the season the barley on the strip not treated with copper died out completely and its place was taken by a small green rush. On the copper treated land the barley matured normally.

The appearance of this bare strip in the barley stubble is shown in Fig. 3.

Fig. 3.—Complete failure of barley on rows where the previous crop of cabbages received no bluestone on Mr. E. Cake's property, Lake Saidie. This photo was taken on September 18th, 1939, and shows that the barley plants, which in March had made growth of the type illustrated on the left of Fig. 2, had died and the remains had largely blown away where no bluestone had been applied, their places being taken by the strip of small green rushes.

The experiments here described were carried out with the assistance of Mr. T. H. Tonkin and involved a factorial experiment with tomatoes and randomised block experiments with onions and peas.

The previous cropping history of the land was potatoes 1936, bare 1937, cabbages 1938. It was probable that the type of soil deterioration common to this area had begun to manifest itself and the need for special treatment would be apparent.

In fact, Mr. Tonkin had observed improved growth where bluestone had been applied in the 1938-39 season to certain tomato plants growing on the margin of the area under cabbages.

1. *Tomatoes.*

On account of his interest in the current investigations, Mr. T. H. Tonkin offered to assist in special experimentation on Lake Saidie and agreed to undertake the work of harvesting the produce from each of 192 tomato plants. Each plant represented a plot in a factorial experiment of the same design as that used with potatoes. The Cristafoulis variety was selected for the experiment and the seed beds sown under glass on July 29th, 1939. In the late spring the seedlings were planted out on the selected area on a 5 ft. x 5 ft. grid. The first block (plots 1-64) was planted on October 29th, the second (plots 65-128) on November 10th, and the third (plots 129-192) on November 12th, 1939.

The land selected for the experiment was well cultivated and in good condition at the time of planting. Portion of the fertiliser was applied to each seedling at time of planting out and the balance on December 3rd, 1939. The latter application was sprinkled on the ground in a 5-foot square about each plant and the soil then ploughed up to the plants.

Where copper was applied the early growth of the plants was good practically without exception. Foliage was normal and fruiting satisfactory. Those plants receiving no copper made inferior growth, appeared unthrifty and, in some instances, died out and were replaced. Replants failed to make satisfactory growth. A few plants on the copper-free treatments made fair growth and produced a certain amount of fruit. It is thought that these cases represent contamination of the ground by ashes, stock manure or some such factor. In spite of these anomalous plants, the crop without copper could be described as a complete failure as a commercial proposition.

Fig. 4.—Representative tomato plants grown with and without bluestone on Mr. T. H. Tonkin's property, Lake Saidie.

64: No bluestone.

60: Plus bluestone, 5 lbs. per acre.

Both plants were photographed on January 16th, 1940, from the same distance.

Observations made on the copper deficient plants during the growing period revealed a number of characteristics. In comparison with the copper treated plants only a fraction of the growth was made (Fig. 4), the small amount of fruit produced was of poor quality, the leaves were smaller and stiffer, and the upper leaves showed a marked tendency to roll upwards with the midrib as axis. Similar symptoms have been described by Piper, 1940, p. 202. The necrotic areas mentioned by Piper were not observed in this experiment. When picked, the large vigorous leaves of the copper treated plants rapidly became flaccid and drooped, but the smaller, rolled leaves from the deficient plants held their shapes. These leaf characteristics are illustrated in Fig. 5. Other varieties, of course, may exhibit different symptoms.

The picking commenced on December 28th, 1939, and continued for about 11 weeks during which period the fruit from each plant was picked, weighed and recorded. The yield results are given in Table 10 and show a spectacular response to the bluestone applications. Five pounds per acre seems inadequate, but an application of 10 pounds of bluestone per acre has given maximum returns. As the figures show that no effect on yield results when manganese or zinc is added to the mixture at any of the levels used, it must be concluded that these elements are not at present necessary in the fertiliser mixture on this type of soil. As mentioned above, marly patches may need other micro-elements, particularly manganese, in addition to the copper.

TABLE 10.

EFFECT OF MICRO-ELEMENTS ON THE YIELD OF TOMATOES ON MR. T. H. TONKIN'S PROPERTY, LAKE SAIDIE.

Seeded 29th July, 1939. Planted out—1–64, 29th October, 1939; 65–128, 10th November, 1939; 129–192, 12th November, 1939.

Commenced picking 28th December, 1939. Finished picking 14th March, 1940.

Basal Fertiliser—Potato manure G*, 12 cwt. per acre.

Special Fertiliser Treatment.		Yield of Fresh Fruit.
Fertiliser.	Rate per acre.	
	lbs.	lbs. per acre.
Manganese sulphate level	*nil*	26,800
(with all combinations of the other micro-elements) ...	5	28,100
	10	27,500
	20	28,600
Bluestone level	*nil*	5,500
(with all combinations of the other micro-elements ...	5	28,200
	10	39,000
	20	38,300
Zinc sulphate level	*nil*	27,300
(with all combinations of the other micro-elements) ...	2½	25,800
	5	30,900
	10	27,000
Difference for significance P = ·05	...	4,300

*For analysis of Potato manure G see the Appendix.

Fig. 5.—Photograph showing the stiff and curled leaves characteristic of tomato plants of the Cristafoulis variety grown without bluestone in contrast with the large vigorous leaves of the copper treated plants on Mr. T. H. Tonkin's property, Lake Saidie. Photograph taken January 16th, 1940.

2. *Onions.*

The experiment with onions was planted adjacent to the tomatoes but on land less effectively drained. Brown Spanish seed was sown in a seed bed on June 30th, 1939. The seed bed was divided into six sections and each one fertilised with one of the mixtures to be used in the experiment (see Table 11). Little response to this seed bed treatment was noted either in the seed bed or on the plots.

On October 12th, 1939, the experimental area was ploughed, the fertiliser mixtures being applied in the appropriate furrows in the course of the operation. The onion seedlings were then planted in the ploughed soil above the manure. Growth was never vigorous and no responses or characteristic symptoms could be detected at any period. At harvest the onions were pulled and weighed without removing the partly dead tops. Yield data are given in Table 11 and show no significant differences resulting from the treatment. Apparently the conditions were unsuitable for the growth and response of onions.

TABLE 11.

YIELD OF BROWN SPANISH ONIONS ON MR. T. H. TONKIN'S PROPERTY, LAKE SAIDIE.

Seeded 30th June, 1939. Planted out 12th October, 1939. Harvested 7th March, 1940.

No.	Fertiliser Treatment.		Yield (tops and bulbs).
	Mixture.	Rate per acre.	
			lbs. per acre.
1	Control—Potato manure G	12 cwt.	15,100
2	Control plus bluestone	5 lbs.	17,800
3	Control plus bluestone	10 lbs.	12,700
4	Control plus bluestone	20 lbs.	15,300
5	Control plus bluestone	10 lbs.	16,800
	Control plus manganese sulphate	10 lbs.	
6	Control plus bluestone	10 lbs.	13,600
	Control plus manganese sulphate	10 lbs.	
	Control plus zinc sulphate	5 lbs.	
	No significant differences at P = ·05		

3. *Peas.*

Garden peas were seeded adjacent to the onions with the same treatments. The land was very wet and the growth of the peas generally so poor that the experiment was abandoned. No indication of response to treatment was observed.

B. *Experiments with Maize.*

Experiments with maize were planted on Mr. J. Rutherford's property, Torbay, and on the Denmark Research Station.

1. *Mr. J. Rutherford's property, Torbay.*

Mention has been made (Teakle and Morgan, 1939, page 126) of the benefit of bluestone applications for the growth of maize on bottlebrush country of the Plantagenet peaty sand type on this property. To obtain more precise information, a small experiment on portion of this area was laid down in November, 1939, to determine the most economical rate of application of bluestone.

The experiment established the benefit to be derived from bluestone as a fertiliser and showed that 10 lbs. per acre applied with the usual fertiliser gave optimum returns. Heavier applications were of no advantage. Furthermore, it was again observed that practically normal growth occurred without the use of bluestone on the sites of old ash beds. By contrast, on other portions of the plots not treated with bluestone, the maize did not grow beyond the seedling stage, exhibited, in the early stages, symptoms such as pale yellow tipping of the leaves, poor rooting system and weak stems, and finally collapsed as a rotting mass on the ground. A certain amount of a chlorotic stripe occurred on some plants. Normal growth was made where bluestone was used, but exceptionally dry summer conditions did not permit heavy growth to be made.

Yield data are given in Table 12.

Table 12.

EFFECT OF BLUESTONE ON THE YIELD OF MAIZE AS A FORAGE CROP ON PLANTAGENET PEATY SAND ON Mr. J. RUTHERFORD'S PROPERTY, TORBAY.

The growth of Maize on the Copper-deficient land where there is no effect from Ashbeds is illustrated by the figure at the bottom of the table.

Planted 23rd November, 1939; harvested 4th March, 1940.

No.	Fertiliser treatment.		Green matter.
	Mixture.	Rate per acre.	
			tons per acre.
1	Control—Potato manure H (average growth on plots, including ashbeds)	3 cwts.	2·2
2	Control plus bluestone	10 lbs.	8·3
3	Control plus bluestone	20 lbs.	8·3
4	Control plus bluestone	40 lbs.	7·7
	Control, excluding ashbeds	...	0·9

Figure 6 illustrates copper deficient maize plants in comparison with healthy plants growing on adjacent copper treated strips.

Following the cutting of the maize for forage, oats were sown as a winter crop without further fertiliser treatment. Similar responses were observed but it was obvious that other factors were affecting growth on portion of the area as there were patches, irrespective of copper treatment, on which the oat plants were stunted in growth and exhibited a stripe chlorosis. With the advancing season the chlorotic stripes merged to give a pale yellow chlorosis. Nutritional aspects of this disorder are being investigated.

Fig. 6.—Maize plants grown with and without bluestone on Plantagenet peaty sand on Mr. J. Rutherford's property, Torbay.

Left: Maize with bluestone at the rate of 10 lbs. per acre.

Right: Maize without bluestone.

Note the diminutive size, the failure of the stems to elongate, the poor root systems and the stringy withering of the leaves. Photograph taken January 18th, 1940.

2. *Denmark Research Station.*

Experiments with maize on the Denmark Research Station during the summer of 1939-40 gave inconclusive results but observations indicated some response to copper on one site and perhaps to copper plus manganese plus zinc on another site. Both sites were on a grey sandy soil carrying stunted jarrah timber. This has been mapped as the Kwilalup sand (Burvill, 1939) but is related in some respects to the Plantagenet peaty sand of the bottle brush flats. (Hosking and Burvill, 1938.) After the maize was harvested, oats were grown during the winter of 1940. The crop was virtually a failure on one site but on the other, in the south east corner of the Research Station, control strips were affected in patches by severe copper deficiency symptoms which were eliminated on adjacent plots by the copper containing fertilisers.

C. *Experiments with vegetables on Mr. B. H. Burvill's property, Little Grove.*

Reference to the value of manganese as a fertiliser for potatoes on grey, marly marsh soils of the Little Grove district has been made by Teakle and Morgan (1939). Evidence of the response of swedes and cabbages to copper was observed but no yield data obtained. Current work with potatoes has been discussed above and the results of collateral randomised block experiments with tomatoes, peas and swedes are here reported.

1. *Tomatoes.*

The piece of land selected for the tomato experiment conformed to the general characters of the marly type on this marsh, but lay adjacent to the sandhill on the eastern fringe. The variety used was Chalk's Early Jewel and the seedlings were planted on November 14th in rows with a spacing of five feet between the plants and between the rows. Each plot consisted of seven seedlings and a spacing of six feet was allowed between the ends of the plots.

The basal fertiliser used was potato manure H* at the rate of 12 cwts. per acre and the micro-elements were applied as mixtures with the basal fertiliser. Fertiliser mixtures for each plot were applied by hand on the prepared land in a band about 9 inches wide and worked in with the rotary hoe. Immediately after the working the tomato seedlings were planted along the fertiliser band.

The bulk of the seedlings survived the planting out and, where the fertiliser mixture was suitable, satisfactory growth was made. In general, the growth was more vigorous near the margin of the marsh and the most severe injury from mineral deficiency occurred in the blocks some distance from the margin. Here some of the plots receiving no copper were practically complete failures, whereas fair yields were obtained, even without copper, on the soil near the sandhills. This variation in the nutritional status of the soil within the same soil type presents a serious disability in the interpretation of results which do not differ by considerable amounts. The plants most seriously affected by mineral deficiency made very little growth and developed a small bunchy top of yellow, unhealthy leaves. Generally the symptoms were quite different from those observed at Lake Saidie with the Cristafoulis variety. This may be due to difference in varietal response, or, more probably, to the totally different soil conditions, including high calcium carbonate content and manganese deficiency. Where the deficiency was least severe no characteristic symptoms were exhibited, but only medium growth was made and the fruit was generally small and of inferior quality.

When examined on January 17th, 1940, the appearance of the plants on the controls and plots receiving manganese but no copper were described as poor; on the plots receiving copper, plants were described as good and it was considered that those receiving copper, manganese and zinc were somewhat superior in vegetative appearance.

Picking commenced on March 2nd and continued until April 25th. Mr. Burvill confined his picking to sound fruit only, but in order to get a better estimate of the yields, on a number of occasions all fruit was picked and weighed. It was felt that fruit discarded on account of various causes such as over-ripeness, injury by insects, etc., should be included in the yields obtained to estimate the effect of the treatments.

Observations showed that the treatment had very little effect on the date on which the tomatoes were ready for picking, but there was very considerable differences in the quantity and quality of the fruit from the various treatments.

Yield data are given in table 13.

* For analysis of Potato manure H see the appendix.

TABLE 13.

EFFECT OF MICRO-ELEMENTS ON THE YIELD OF TOMATOES, PEAS, AND SWEDES ON GREY, MARLY MARSH SOIL ON MR. B. H. BURVILL'S PROPERTY, LITTLE GROVE, SOUTH ALBANY.

Planting Details.

	Tomatoes.	Peas.	Swedes.
Planted	14th November, 1939.	14th November, 1939.	15th November, 1939.
Commenced picking	2nd March, 1940.	29th January, 1940	10th February, 1940.
Finished picking ...	25th April, 1940.	15th February, 1940.	19th February, 1940.

No.	Fertiliser treatment. Mixture.	Rate per acre.	Tomatoes (lbs. of fresh fruit per acre).	Peas (lbs. of green peas per acre).	Swedes (lbs. of roots per acre).
1	Control—Potato manure H *	12 cwts.	7,700	105	2,900
2	Control plus manganese sulphate	10 lbs.	10,200	*nil*	11,400
3	Control plus manganese sulphate	20 lbs.	10,800	1,300	23,000
4	Control plus manganese sulphate	40 lbs.	11,500	160	13,000
5	Control plus manganese sulphate ... ... plus borax	20 lbs. 5 lbs.	12,200	*nil*	10,600
6	Control plus manganese sulphate ... ... plus zinc sulphate	20 lbs. 5 lbs.	15,500	*nil*	7,700
7	Control plus bluestone	20 lbs.	32,000	5,000	31,400
8	Control plus bluestone ... ... plus manganese sulphate	20 lbs. 20 lbs.	33,000	9,100	32,000
9	Control plus bluestone ... ... plus manganese sulphate ... ... plus zinc sulphate	20 lbs. 20 lbs. 5 lbs.	38,000	7,800	39,000
10	Control plus bluestone ... ... plus manganese sulphate ... ... plus zinc sulphate	10 lbs. 10 lbs. 5 lbs.	30,000	6,900	32,000
	Difference for significance at P = .05 ...	...	9,000	2,800	...

* Modified for peas to supply one-quarter of the normal nitrogen in potato manure H.

These results show that the outstanding effect on yield is due to copper. Although there is a slightly higher yield from the plots receiving copper, manganese and zinc, the variation between the yields in the different plots renders this difference of doubtful significance. The copper, manganese and zinc treatment gave the highest yield in four out of the six blocks, but a more substantial difference would be desirable before more definite conclusions could be drawn.

The quality of the fruit on plots receiving copper was generally excellent but, unfortunately, yield differences do not reflect the superiority due to the quality factor. It is very difficult to obtain reliable estimates as to quality, but observation indicated that the fruit on the control plots was generally poor to useless in quality for commercial purposes, that on the plots receiving copper alone was good to excellent, while that on plots receiving copper and manganese in combination appeared to be best. It seems significant that the plants receiving copper and manganese in combination continued producing sound fruit for a longer period than the other treatments. On March 11th practically all treatments were yielding at least a certain amount of sound fruit, but by April 7th the amount of marketable fruit on the plots receiving no copper was very small.

In practice, it may be desirable to use a small dressing of manganese sulphate with the bluestone for tomatoes.

2. *Garden Peas.*

Garden peas were planted on the same marly soil type, but the site selected was on new land situated some distance from the margin of the marsh. The land was worked by means of a rotary hoe to which a device was attached to open out a furrow in which the fertiliser was applied and worked in with the same implement prior to sowing the seed. The seed was then sown in a row above the fertiliser and covered by means of a rake. The fertiliser used was a modified type of potato manure H supplying nitrogen at one-quarter the rate used in the ordinary formula. The application was equivalent to 67 lbs. of sulphate of ammonia, 820 lbs. of superphosphate and 255 lbs. of sulphate of potash per acre.

Germination of the peas was generally satisfactory but differences due to treatment were early observable. When examined on January 17th, the controls were generally poor and inferior to all other treatments. Both copper and manganese alone improved the early growth, but the most robust top growth occurred where copper and manganese in combination were used. No definite symptoms could be isolated; a general unthriftiness characterised the plants suffering from the mineral deficiency. With the advance of the season the vegetative growth improved under all treatments and the greatest difference resulting from the treatment was in the yield of green peas. The yields of green peas from the various treatments are given in Table 13.

Again copper produced the most marked effect on the yield of the peas, but it was considerably improved by the addition of manganese to the copper. Manganese was not effective in the absence of copper. Zinc appeared to have no value as far as the yield was concerned, but Mr. Burvill observed that the peas were ready to pick earliest on the plots which had received zinc. However, in the absence of technical assistance at the time, it was not possible to commence picking until the rest of the area was ready and, on this account, it is likely that the pea vines receiving zinc would deteriorate in yield capacity earlier than those on which picking was commenced at the correct time.

The best type of marketable peas was produced on plots receiving copper and manganese in combination. It is interesting that the main effect of the mineral deficiency was the failure to produce seed in the pods. The controls and the plots receiving manganese sulphate at 10 lbs. and 40 lbs. per acre, produced very small pods and no peas. The other treatments involving manganese but no copper produced fair sized to large pods, containing only odd peas or none at all. Such pods are generally known as "windbags."

3. *Swedes.*

The swedes were planted on November 15th, 1939, on new land of the same type near the site of the experiment with peas. The same general technique as that used for peas was adopted, but the fertiliser was the same as for the tomatoes and was applied at the rate of 12 cwts. per acre in the row prior to sowing the seed.

When examined on January 17th, the swedes had made generally healthy growth without definite deficiency symptoms being apparent, the main differences being in the vigour and size of the plants. The chlorosis observed in 1938 did not appear on this new ground. Copper alone produced very obvious improvement in growth but the combination of copper and manganese was superior as far as the appearance of the tops was concerned.

Harvesting commenced on February 10th. Apparently due to the excessively dry season, the roots were generally ugly in shape and multiple tap roots were produced in many instances, particularly where the tops were most vigorous. The foliage was most vigorous on the copper plus manganese plots. As a brown

discolouration of the pulpy portion of the root rendered the swedes unmarketable, complete yield data were not obtained. Only two blocks were harvested with the results given in Table 13. It is apparent that manganese alone has had some effect on the yield of roots, but the principal effect is due to copper. It is possible that maximum yields will be obtained from the use of copper and manganese together. Mr. Burvill observed that the zinc appeared to increase the earliness of the swedes. Although the yield was not improved, roots were ready to pull on the zinc treated plots two weeks earlier than on other treatments.

IV. SOIL AND PLANT ANALYSES AND COPPER DEFICIENCY.

Farmers are persistent in their confidence in soil analysis as a means of detecting and providing a cure for all forms of soil deficiencies. Samples are continually being received with the request that an analysis be made and the appropriate advice given. It would be of great advantage if this method were reliable but, except where backed by a considerable body of experience, soil analysis generally fails to answer such questions. Soil analyses are of great value in some directions and are used for special purposes, but for the detection of mineral deficiencies other methods are more satisfactory.

The most satisfactory method is the field trial but this is time consuming and involves delay. Pot tests with the soil in question are of value but need considerable equipment and experienced experimenters. Plant analysis promises considerable assistance once a body of evidence has been built up to correlate field experience with the laboratory data. This method is relatively rapid and far less expensive than the field or pot test and it is hoped that suitable indicator species properly sampled may be of great value in future work.

A number of analyses have been made in the Government Chemical Laboratory in connection with the field work reported above and are detailed in Tables 14 and 15.

TABLE 14.

ANALYSES OF PLANT MATERIAL FOR MICRO-ELEMENT CONTENT.

Location.	Crop.			Fertiliser treatment.	Analysis, ppm dry matter.	
	Variety.	Date planted.	Date sampled.		Cu.	Mn.
(a) Young but Mature Leaves.						
Poole — Two People Bay	Potatoes	....	....	Control—No bluestone—1	1·8	75
				2	1·5	72
				20 lbs. bluestone per acre broadcast—1	4·4	26
				2	3·4	35
Martin — Lake Saidie	Potatoes	20th October, 1939	16th January, 1940	Control	3·1	80
				Bluestone and manganese sulphate, each 15 lbs. per acre, plus zinc sulphate, 5 lbs. per acre	4·1	79
Blake — Lake Saidie	Potatoes	24th October, 1939	16th January, 1940	Control	3·5	124
				Bluestone, 5 lbs. per acre	3·9	143
				Bluestone, 10 lbs. per acre	5·4	107
				Bluestone, 20 lbs. per acre	2·1	105
Tonkin — Lake Saidie	Tomatoes	29th October, 1939	16th January, 1940	Control	3·0	84
				Bluestone, 5 lbs. per acre	2·5	65
				Bluestone, 20 lbs. per acre	3·8	84
(b) Leaves 6 and 7 from Base.						
Rutherford—Torbay	Maize	23rd November, 1939	18th January, 1940	Control	1·9	93
				Bluestone, 10 lbs. per acre	3·6	89

TABLE 14—*continued.*

ANALYSES OF PLANT MATERIAL FOR MICRO-ELEMENT CONTENT—*continued.*

Location.	Fertiliser treatment.	Moisture, per cent. fresh tubers.		
	(c) Potato Peel and Pulp.			
Martin—Lake Saidie—Peel	Control	83·2	2·0	N.D.
	Bluestone	80·0	1·9	N.D.
Pulp	Control	83·2	2·1	N.D.
	Bluestone	80·7	0·9	N.D.
Burvill—Many Peaks—whole tubers	Lbs. per acre of sulphates of—			
	Cu. Mn. Zn.			
	....	76·8	1·5	4·1
	....	78·6	1·8	4·1
	5 5 5	78·2	1·5	4·1
	5 5 5	78·7	1·4	4·4
	20 10 2½	76·8	1·4	4·1
	20 10 2½	77·2	1·4	4·1

TABLE 15.

ANALYSES OF PEEL AND PULP OF POTATO TUBERS GROWN ON VIRGIN PEAT AT MANY PEAKS.

Copper and Manganese figures are given in Table 14.

Plot No.	Special Fertiliser treatment—lbs. per acre of Sulphates of:			Moisture per cent. fresh tubers.		Minerals—(per cent. oven dry material):									
						Ash.		CaO.		MgO.		K_2O.		P_2O_5.	
	Cu.	Mn.	Zn.	Peel.	Pulp.	Peel.	Pulp.	Peel.	Pulp.	Peel.	Pulp.	Peel.	Pulp.	Peel.	Pulp.
100	....	....	....	80·8	76·8	4·54	3·20	·03	Tr.	·167	·098	2·71	1·83	·281	·313
138	....	....	....	80·2	78·6	4·66	3·98	·04	Tr.	·163	·101	2·75	2·32	·459	·485
99	5	5	5	78·9	78·2	4·26	3·64	·03	Tr.	·170	·130	2·49	2·16	·274	·268
139	5	5	5	79·3	78·7	4·47	4·25	·04	Tr.	·152	·101	2·61	2·46	·395	·408
101	20	10	2½	78·8	76·8	4·45	3·38	·02	Tr.	·181	·116	2·61	2·03	·274	·268
137	20	10	2½	79·6	77·2	4·23	3·54	·03	Tr.	·156	·091	2·49	2·03	·446	·478
	Average			....	77·7	....	3·66	....	Tr.	....	·106	....	2·14	....	·370

Note.—K_2O results calculated to per cent. of ash, show remarkable constancy between the limits 57·2 and 60·1 over the twelve samples.

These figures give little evidence of the value of analyses of leaves or tubers of the potato or leaves of the tomato plant as a means of detecting copper deficiency. On known copper-deficient land, copper fertilisers had little consistent effect on the copper content of the leaves, peel or pulp. The potato peel and pulp are especially low in copper, irrespective of the treatment. Apparently tomatoes and potatoes may not be of much value as chemical indicators of copper deficiency.

At Many Peaks, micro-element fertilisers had no measurable effect either on the yield or on the mineral composition of potato peel or pulp. The comparison of analyses of duplicate samples taken from different blocks indicates that environmental conditions have had more effect on composition than variations in treatments with micro-element fertilisers. The similarity in composition of peel and pulp is interesting and unexpected.

The information in Table 14 does not point to manganese deficiency with respect to any of the samples examined. The variations with treatment in the same experiment are not consistent and no explanation is offered. Unfortunately data were not obtained for material from Little Grove where manganese deficiency has been established for potatoes and certain other crops.

Other crops such as maize, subterranean clover and oat seedlings may be more useful as chemical indicators of copper deficiencies and will be investigated more thoroughly in the future.

V. DISCUSSION.

While this work is of considerable interest and importance to farmers using these and similar soil types, it has a more general value in providing information regarding the behaviour of various crops under a range of conditions. The symptoms observed provide useful information for diagnosis elsewhere and the chemical work will establish the value of species as chemical indicators. The chemical work also provides data useful to workers in animal and human nutrition regarding the supply of elements by these foods in the diet. More fundamental information of this type is urgently required and it is hoped that future experimental work along these lines will be possible.

The value of the refined bluestone as a fertiliser directs attention to cheaper copper-containing substances such as copper ore and roaster residues. These have already proved useful in the wheat belt (Teakle, Thomas and Turton, 1941, p. 70) and ground copper ore is being used in one district. Observations in the Albany district indicate, however, that copper ore may be less effective than bluestone for potatoes, pumpkins and tomatoes. Further work is planned for the coming season to secure precise information before any recommendation is made.

It may be concluded that—

1. Certain soil types in the Albany district require the use of copper-containing fertilisers for satisfactory growth of a number of crops including potatoes, tomatoes and maize. Land which has deteriorated under previous crops gives the greatest response but a substantial response is observed on new land.

2. Dressings of from 5 to 10 lbs. of bluestone per acre appear sufficient. There is an indication that some advantage may be gained by the use of a small dressing of bluestone in succeeding years.

3. Certain marly soil types require both copper and manganese in the fertiliser mixture.

4. Crops differ in their response to micro-elements on deficient soils. For instance, on marly soil copper was of prime importance for tomatoes and manganese for potatoes.

5. Analysis of crop material, in certain cases cited, provides little evidence of the nature of soil deficiencies or response to fertiliser treatments. In other cases analytical data have considerable value for diagnostic and nutritional viewpoints.

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Special acknowledgment is made of the collaboration of the farmers on whose properties the experiments were carried out. Experimental work necessarily involves inconvenience and loss of time and, in some cases, causes pecuniary loss on account of the use of unsatisfactory treatments. With respect to the experiments with tomatoes and peas, Mr. B. H. Burvill and Mr. T. H. Tonkin gave a great deal of their personal time in weighing the produce and keeping the records. To these gentlemen the special thanks of the authors are extended.

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APPENDIX.

COMPOSITION OF MIXED FERTILISERS AS USED IN THE ABOVE EXPERIMENTS.

Guaranteed percentage.

	Nitrogen (N), Ammonia.	Phosphoric Oxide (P_2O_5), Total.	Potash (K_2O), Sulphate.
Potato Manure—B ...	3·75	15·6	4·5
E ...	3·5	15·0	8·0
G ...	3·5	11·3	16·0
H ...	4·0	13·7	9·0

IV. EXPERIMENTS AT MUCHEA AND MAIDA VALE.

By L. J. H. Teakle and G. H. Burvill.

Summary.

Fertiliser experiments conducted with a variety of crops and pastures at Muchea and Maida Vale are described. These centres are in the neighbourhood of the Perth Metropolitan area.

The experiments were on a diatomaceous swamp soil at Muchea and on semi-swamp and poor sandhill country at Maida Vale.

The value of copper compounds included in the fertilisers has been proved for a variety of crops especially maize, Sudan grass, oats and Japanese millet.

With lupins on poor whitish sand at Maida Vale only complete nutrient mixtures have effected substantial improvements in the very poor stand normally obtained with superphosphate. Perennial veldt grass roots have established vigorous plants (ungrazed) in all plots of the 1938 lupin experiment irrespective of the fertiliser treatment.

The results are reported as it is thought that a number of farmers may be interested and desire to ascertain the responses to copper-containing fertilisers on similar land on their own properties.

A. *Mr. J. H. Locke's property, Muchea.*

Experiments were carried out with potatoes, maize, Sudan grass and Japanese millet on black swampy soil on an area known as Lake Chandler, which lies 35 miles north of Perth and less than 30 miles from the Midland Junction stock markets. The area is fed by a number of fine springs of excellent water and, with drainage and a certain amount of irrigation, should prove very productive in the future.

The soils of Lake Chandler are of a dark grey to black mineral type. The mineral matter is largely an assemblage of siliceous cases and fragments of diatoms mixed with sponge spicules and a little sand. This is impregnated with black organic matter. A white, cemented, diatomaceous earth forms a hardpan at a depth of a few feet at many sites. From observations in more or less protected areas it seems likely that a certain amount of peat at one time covered the surface, probably to a depth of about one foot, but has been destroyed by a succession of fires during dry periods since occupation of the State by the white man.

Analysis showed the soils to be acidic in reaction (averaging pH 5) and there is some tendency to salt accumulation in patches. During the winter months the area is usually inundated but no steps have yet been taken to improve the natural drainage of the area.

The seasonal rainfall for Muchea is indicated by the following records for Gingin which lies about 10 miles to the north.

Year.	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Gingin, 1939	137	144	6	20	406	870	909	751	47	175	135	14	3,614
1940	167	2	5	19	175	364	365	171	223	238	45	130	1,904
Average 51 years to 1939	29	43	78	119	442	618	640	507	305	222	56	44	3,103

These show that the district normally receives very little rain during the months of November, December, January, February and March; this means that natural or artificial irrigation would be needed to ensure the production of vigorous summer crops.

In the virgin state these soils carry paperbark (*Melaleuca* spp.) in patches and strips, leaving open spaces up to an acre in extent. The experiments were laid down on one of these open spaces as soon as the water had subsided sufficiently—early January, 1940, in this instance. In the absence of more suitable implements the land was cultivated with a Sunderseeder plough drawn by a caterpillar type tractor. Unfortunately these implements caused an undesirable amount of packing and the tilth was far from perfect at the time of planting. Cultural

and seeding operations were commenced on January 11th, 1940, and finished the following day. Four fertiliser mixtures were used:

1. Potato manure E*, control,—12 cwts. per acre for potatoes and 3 cwts. per acre for maize, Japanese millet and Sudan grass.
2. Control plus 18 lbs. of bluestone per acre.
3. Control plus 18 lbs. of manganese sulphate per acre.
4. Control plus 18 lbs. bluestone plus 18 lbs. manganese sulphate plus 6 lbs. zinc sulphate per acre.

Several inspections were made during the growing period. On February 14th, 1940, the potatoes were starting nicely but no responses were discernible. With the other crops marked differences were apparent; on the plots receiving no copper growth was poor and copper deficiency symptoms showed up in the forms of characteristic leaf tipping and poor rooting systems; where copper had been applied growth and appearance were normal. Sudan grass seemed most sensitive to the copper deficiency and portions of the rows receiving no copper were showing signs of dying out.

As the season advanced these differences magnified. In addition the potatoes without manganese developed a yellowish green foliage colour and made somewhat unthrifty top growth in comparison with the more normal rows receiving manganese. It is interesting that yellowish foliage in potatoes is characteristic of acutely manganese deficient soils at Little Grove, Albany. By contrast, copper deficiency in potatoes is commonly indicated by a dark green foliage somewhat reduced in size.

By April, 1940, maize, without copper, was only 18 inches tall and had developed, in parts, a marked striped chlorosis of the leaves in addition to the characteristic leaf tipping. In some instances leaf tips had died before emergence and had remained trapped in the leaf sheaths, giving the plants a distorted appearance. With copper additions the plants were normal in appearance and 30 to 40 inches tall. The actual size of the leaves did not appear to be proportionately larger than on the control rows, but the appearance of the plants was quite different as internodal stem elongation was restricted where the copper fertilisers were not used. In consequence the leaves of the affected plants trailed on the ground, giving a conifer-like shape.

The growth of the maize appeared to be slightly improved by manganese alone or in combination with copper.

With millet the response to copper was obvious but less consistent. Apparently millet is less sensitive to copper deficiency than either maize or Sudan grass.

Sudan grass proved most severely affected. Without copper, the growth was very poor and tussocky in habit and leaf tipping was very severe. Only a few plants produced small heads and these were only about one foot high. With copper the plants grew normally and headed out at a height of three to five feet. It was noted, however, that seed was not formed, probably due to the hot, dry weather conditions during growth.

A severe frost on April 11th, 1940, killed the foliage of the potatoes and maize and further growth was not made. Consequently harvesting was carried out as early as possible to secure yield data as evidence of the crop responses. Of course,

* The guaranteed analysis of potato manure E was nitrogen (N), 3.5 per cent. (ammonia), phosphoric oxide (P_2O_5), 15 per cent., and potash (K_2O), 8 per cent. (sulphate).

yields were disappointingly low. The severe, hot, dry weather of February, March and April, in the absence of irrigation, retarded early growth and the frost prevented recovery and rapid autumn growth which would have been possible with April rains. The yields of the crops harvested are given in Table 1.

TABLE 1.

YIELD OF CROPS ON MR. J. H. LOCKE'S PROPERTY, MUCHEA, UNDER VARIOUS FERTILISER TREATMENTS.

Planted 11th and 12th January, 1940. Harvested 23rd and 24th April, 1940.

The "seed" potatoes for this trial were obtained from Harvey District.

Fertiliser Treatment.	Potatoes.†	Maize.‡		Sudan Grass
	Tons per Acre.	Tons per Acre.	General height range, excluding tassels.	Tons per Acre.
			inches.	
A. Control—potato manure E*	1·2	0·5	9–16	Too short to cut.
B. Control plus bluestone, 18 lbs. per acre	1·4	3·2	30–45	1·2
C. Control plus manganese sulphate, 18 lbs. per acre	1·4	0·7	9–18	0·1
D. Control plus bluestone 18 lbs. per acre, manganese sulphate 18 lbs. per acre, zinc sulphate 6 lbs. per acre	1·8	3·8	40–48	1 2

* 12 cwt. per acre for potatoes, 3 cwt. per acre for maize and Sudan grass. † Mostly small, immature tubers. ‡ Dried foliage, killed by frost.

The results show that the effects on the growth of potatoes were inconclusive but that copper was of outstanding value for maize and Sudan grass. As the potatoes did not reach maturity owing to the killing frost, it may be argued that the beneficial effects of copper or manganese, not yet apparent in the tubers, would have developed in the later stages of growth. It seems more probable, however, that the failure to secure positive response to bluestone with the potatoes was due to the quality of the "seed" which was grown in the Harvey district. It has been shown by Teakle, Morgan and Turton (1941) that "seed" potatoes from Benger, a few miles south of Harvey, give good yields and show little or no response to bluestone on new land at Lake Saidie, in the Albany district, whereas "seed" grown on light forest soil on the Denmark Research Station required the inclusion of copper in the fertiliser mixture for maximum returns. It is possible that this sample of Harvey seed carried similar virtues to that from Benger, and that, with potatoes, the copper deficiency, manifested by the other crops, was obscured.

In a less severe season, with drainage to enable an earlier planting and the use of the springs to provide a certain amount of irrigation, good crops of summer forage may be expected on this swamp where appropriate fertilisers are used. Being so favourably situated with respect to the Midland Junction stock markets, such land would be of considerable value and warrants capital expenditure for drainage and other necessary improvements.

B. *Maida Vale.*

Arising out of the interest of the late Mr. F. Wittenoom in experimental work, a number of fertiliser trials have been conducted on his property at Maida Vale with a view to establishing pastures and crops on certain soils and restoring crop

vigour on others. Experiments with potatoes have been reported by Teakle and Morgan (1939) and show no effect from special treatment. Other experiments have been carried out on moist land resembling, in some respects, the Plantagenet peaty sand type of the Albany district, and also on a rise of poor whitish sand. In the virgin state this rise carried a variety of scrubs including woolly bush (*Adenanthos cygnorum*) and coastal blackbutt (*Eucalyptus Todtiana*). The soil is recognised to be extremely poor in fertility, acidic in reaction (pH 5) and is related to the Muchea sand described by Hosking and Greaves (1936). The moist land shows accumulation of organic matter in the surface soil which may be described as ranging from dark grey organic sand to black peaty sandy loam or loam. The reaction generally ranges from pH 4.5 to 5.0. In the virgin state this country carried low scrub (including *Jacksonia floribunda* and *Melaleuca* spp.) with a park-like sprinkling of marri (*Eucalyptus calophylla*), coastal blackbutt and Christmas tree (*Nuytsia floribunda*).

1. *Experiments with moist land.*

On May 19th, 1938, small areas of pastures were top-dressed on four sites with—

(i) Manganese sulphate 20 lbs. per acre.

(ii) Manganese sulphate plus bluestone, each 20 lbs. per acre.

(iii) Manganese sulphate plus bluestone plus zinc sulphate, each 20 lbs. per acre.

On three of these sites representing established pasture of inferior quality, no response was noticed but on the fourth, which had just been resown with subterranean clover, marked response to the copper plus manganese treatment was observed on two sides of the plot. Following this lead an experiment with oats was planted on similar land in an adjoining paddock on May 17th, 1939. The soil proved excessively wet in patches during the winter, but reasonable growth was made. On July 17th the first symptoms of copper deficiency showed on a small patch on a control plot. As the season advanced the copper deficiency symptoms became apparent over considerable portions of the plots receiving no copper and by September the general advantage of the copper treatment was obvious. Neither manganese nor zinc appeared to have any effect whether used alone or in addition to the bluestone.

Unfortunately the block of plots was harvested by the manager of the farm before yield estimates could be made. In order that the experiment would not be completely devoid of quantitative data, straw yields were obtained on December 9th, 1939, to illustrate the responses. The average yield of straw from plots receiving no copper was 2.9 cwts. per acre and from the copper-treated plots 5.4 cwts. per acre. A much more substantial difference in grain yield was expected. It is considered that these experiments established the occurrence of copper deficiency on moist land of this type in the Maida Vale district.

2. *Experiments on the sandhill country.*

Although thoroughly cleared, sown with various pastures and lupins, and well fertilised with superphosphate, most unsatisfactory growth of all species resulted on this poor hill soil. A poor covering of grasses such as silver grass (*Festuca* spp.) with very unthrifty cape weed and lupins, was all that established and represented a very disappointing return in view of the treatment given.

It was decided to experiment with lupins on this type of country to determine the effect of—

(i) Ordinary fertilisers.

(ii) Micro-elements in addition to the ordinary fertilisers.

(iii) A complete nutrient mixture: a modified Hoagland's hydroponics mixture was used.*

The lupin seeds were nicked to facilitate germination, inoculated with appropriate bacteria, and sown in rows with the fertiliser mixtures.

The first block of the experiment was sown on May 6th, 1938; germination was good but subsequent growth was poor. On the plots receiving the complete nutrient mixture a slight improvement was noticed in the first year. In subsequent years, without further fertiliser treatment, the lupins reseeded and, on the plots which had been treated with the complete nutrient mixture, quite a promising stand established. Furthermore, the soil improved in appearance as a result of the accumulation of a litter of lupin leaves. On the other treatments the growth of the lupins could be described as a failure. No yields were obtained in 1938, but in 1939 and 1940, after the seed had been shed, the production of dry tops on each plot was determined.

In view of the slight improvement in 1938 where the nutrient mixture had been applied, another block of treatments was sown in 1939 to include a variety of such mixtures.† Growth was poor the first year, as in the 1938 block, but the advantage of the mixtures became more apparent in the growth of voluntary lupins in 1940 without further fertiliser treatment being used.

In order to restrict leaching, which is likely to be excessive in these sandy soils, the nutrient mixtures were incorporated in some instances with other materials which were expected to be more or less inert nutritionally, but which would protect the more soluble chemicals from the winter rains. Plaster of Paris and sand were used in the 1938 experiment and kaolin in the 1939 experiment. As the effect of the plaster of Paris was not controlled in 1938, the possibility of a beneficial effect from the plaster of Paris must not be overlooked in considering the results. The 1939 experiment indicated that, while the main effect was due to the nutrient mixture, the kaolin also had some beneficial effect. The yield data are given in Tables 2 and 3.

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* The complete nutrient mixture was made by mixing:—

100 parts of ammonium phosphate.
100 parts of potassium nitrate.
400 parts of potassium sulphate.
300 parts of magnesium phosphate.
10 parts of boric acid.
5 parts of bluestone.
20 parts of manganese sulphate.
10 parts of zinc sulphate.
20 parts of iron tartrate.

This mixture was applied at the rate of 530 lbs. per acre.

† The basal nutrient mixture consisted of:—

300 parts of magnesium phosphate.
100 parts of potassium chloride.
200 parts of potassium sulphate.
200 parts of calcium sulphate.
200 parts of calcium nitrate.
100 parts of potassium dihydrogen phosphate,

with small amounts of salts applying boron, manganese, iron, copper, zinc, aluminium, nickel, cobalt, lithium, chromium, tin, iodine, bromine, lead, tungsten and molybdenum.

The mixture was applied at the rate of 6 cwts. per acre.

Table 2.

YIELD OF DRY LUPIN TOPS (EXCLUDING SEEDS AND PODS) UNDER VARIOUS TREATMENTS ON MUCHEA SAND, MAIDA VALE.

Experiment planted 6th May, 1938.

Treatment.	Yield—cwts. per acre.	
	Harvested 8th December, 1939.	Harvested 5th December, 1940.
1. Superphosphate 1 cwt. per acre	1·0	0·6
2. Superphosphate 4 cwt. per acre	0·5	0·3
3. Control—Superphosphate 1 cwt. per acre, sulphate of potash ½-cwt. per acre	1·2	0·4
4. Control plus sulphate of ammonia ½-cwt. per acre ...	0·8	0·6
5. Control plus copper, manganese and zinc as sulphates each 10 lb. per acre, plus magnesium sulphate 20 lb. per acre	0·9	0·5
6. Control plus sulphate of iron ½-cwt. per acre	1·8	0·8
7. Control plus borax 10 lbs. per acre	1·4	0·5
8. Control plus iodine, tungsten, molybdenum and lithium (as various salts) each 5 lbs. per acre	0·9	0·6
9. Complete nutrient mixture plus plaster of Paris (see footnote* page 130)	4·3	2·6
10. No fertiliser	0·4	0·2

Table 3.

YIELD OF DRY LUPIN TOPS (EXCLUDING SEEDS AND PODS), UNDER VARIOUS TREATMENTS ON MUCHEA SAND, MAIDA VALE.

Experiment planted 11th May, 1939.

Treatment.	Yield—cwts. per acre.	
	Harvested 8th December, 1939.	Harvested 5th December, 1940.
1. Control—superphosphate 1 cwt. per acre	0·6	0·2
2. Superphosphate 4 cwt. per acre	0·5	0·4
3. Control plus sulphate of potash ½-cwt. per acre ...	0·6	0·2
4. Control plus sulphate of potash ½-cwt. per acre, kaolin 1,000 lbs. per acre	0·7	0·4
5. Basal nutrient mixture†	0·8	1·1
6. Basal nutrient mixture† plus 1,000 lbs. per acre kaolin	1·1	2·0
7. As 6—but granulated with water before application ...	1·0	1·8
8. Basal nutrient mixture minus nitrogen plus kaolin	1·0	1·4
9. Tricalcium phosphate ½-cwt. plus sulphate of potash ½-cwt. per acre	0·7	0·7

† For composition of basal nutrient mixture see footnote† page 130.

Lupins growing on this soil type without special fertiliser treatment rarely exceed six inches in height, the foliage is generally a yellowish colour and only a few plants succeed in producing a single pod. These are sufficient to maintain a stand of scattered plants in succeeding years but are of little or no feed value. Some improvement in appearance was noticed in the first year of the plots receiving sulphate of iron, borax and the copper, manganese, zinc and magnesium mixture, but quite healthy plants, if small, grew on the complete nutrient mixture plots. In succeeding years in both experiments the plots which had received the complete nutrient mixtures were outstanding in comparison with the other treatments. The foliage growth, though not large, appeared healthy and a considerable amount of seed was produced; furthermore, the litter from the lupins, which were not being grazed, was building up the soil of these plots in a very satisfactory manner.

In 1939 roots of perennial veldt grass (*Ehrharta calycina*) were planted in the centre of each of the plots of the 1938 experiment; all of these have established and grown into excellent crowns in the absence of grazing. It seems that this grass, properly managed, should be of considerable value on soils of the coastal sandhills, particularly when grown in association with lupins.

On soils of such low fertility it cannot be claimed that there is special deficiency of any one element; no doubt the deficiency is general and the supply of practically all of the plant nutrients is required to promote satisfactory growth. Further work is being carried out using commercial fertilisers as ingredients for the complete nutrient mixtures and it is hoped that results of practical value will be obtained in the future. This line of attack on such nutritional problems on poor soils in districts of generous rainfall promises to yield information of considerable scientific and practical value and is being continued in association with officers of the Forests Department on similar soil in the Gnangara pine plantation.

Acknowledgments.

The authors have pleasure in acknowledging the assistance of Mr. J. H. Locke in carrying out the experiments at Muchea and the interest of the late Mr. Frank Wittenoom who made it possible to commence the experiments at Maida Vale. Thanks are also tendered to Messrs. Cuming Smith & Mt. Lyell Farmers Fertilisers Ltd. for the supply of the fertilisers used in the Muchea experiments.

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Teakle, L. J. H., Morgan, E. T., and Turton, A. G. 1941: Experiments with Micro-elements for the Growth of Crops in Western Australia. Jour. Agric. West Aust., 18: 70-86.

"Falling Disease" of Cattle in the South-West.

H. W. Bennetts, Veterinary Pathologist.

INTRODUCTION.

"Falling Disease" was described fully by Bennetts and Hall (1939) who also gave an account of earlier investigations into the cause of this mysterious complaint. The disease, so far as we are aware, confined to the South-Western corner of the State*, is characterised by a seasonal occurrence and sudden death, almost invariably without premonitary signs. In the dead animal a number of changes may be detected but the naked eye appearances are not very characteristic. On microscopic examination, however, definite and typical changes, diagnostic of the disease, are present. These comprise inflammation of the kidney (*glomerulonephritis*) in association with accumulations of iron (*haemosiderin*) in the kidneys, liver and spleen.

It was noted that cows, particularly in affected herds, showed severe anaemia during the months of August to October, this being the period of the year when the disease also occurs. The simultaneous occurrence of these two conditions, anaemia and "falling disease," appeared to be significant and there was reason to suspect that the anaemia was due to a deficiency of copper and possibly of other minerals. Although it appeared extremely unlikely that mineral deficiency could be directly responsible for the deaths of animals affected with "falling disease" it was considered that it might be one factor contributing to the cause of the disease. Accordingly experiments designed to throw some light on the relationship of the anaemia and mineral deficiency to the occurrence of "falling disease" were carried out. The possible contributory effects of a diet composed largely of drooping flowered clover (*Trifolium cernuum*) were also considered.

The experiments referred to have been carried out on two properties, one at Jindong and one at Forrest Grove, which were made available entirely for experimental purposes.

Following the early finding that supplements containing copper would prevent the occurrence of the anaemia it was suggested that stockowners in the affected area would be well advised to feed Denmark No. 1 lick (a limonite lick containing copper) to their milking cows. This lead was followed and during the past three seasons the lick has been extensively used throughout the Busselton-Margaret River and Northcliffe districts.

The results of the experiments and of lick feeding under field conditions are described in some detail by Bennetts, Beck, Harley and Evans (1941). The purpose of this account is to give, briefly, the present position with regard to the investigation.

The cause of "falling disease" has not yet been determined and is still being investigated. Notwithstanding this, however, valuable information, which is not without practical significance, has been obtained.

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* An identical disease occurs on "coasty" country on King Island and sudden deaths in good-conditioned cattle on "coasty" country in Western Australia have been reported frequently. It would appear probable that the W.A. losses are also due to falling disease, but we have had no opportunity of confirming this.

Bennetts, H. W., and Hall, H. T. B. (1939).—J. Dept. Agric., West. Aust., 17 : 41.

Bennetts, H. W., Beck., A. B., Harley, R. H., and Evans, S. T. (1941).—Aust. Vet. J. (in press).

COPPER DEFICIENCY A CONSTANT ASSOCIATION WITH "FALLING DISEASE."

1. *Chemical Findings.* Analyses carried out by Beck and more recently by Evans have shown that pastures from affected properties and animals (cattle and sheep) depastured thereon constantly show a low copper status. Pastures contain from 1.1 to 3.2 parts per million of copper whereas pastures from other parts of the State where stock remain healthy contain above 5 p.p.m. Blood, liver, and milk copper values for cattle are considerably lower than those obtained from "healthy" areas. Blood copper values frequently fall to 0.01 milligramme per cent. or lower, liver copper varies from less than 1-6 p.p.m. and milk copper generally from 0.01-0.02 milligramme per litre. "Normal" values for healthy West Australian bovines are blood 0.07-0.14 milligramme per cent.; liver 37-231 parts per million; milk 0.05 to 0.20 milligramme per litre.

2. *Signs of Copper Deficiency in Animals.*

Where sheep are carried enzootic ataxia ("rickets") of lambs, a disease due to copper deficiency, is a common occurrence.

Cattle throughout the affected area show signs attributed to copper deficiency. In adult cattle manifestations are particularly marked during the period from August to October when, despite abundance of feed, there is some loss in condition, a rough starey coat and evidence of anaemia.

Depraved appetite is common, cows eating soil around the roots and butts of upturned trees.

Temporary sterility is an associated condition. Many cows served during the autumn and winter do not conceive and do not return to the bull, generally, until about November when they are readily stocked.

In calves growth is retarded and there is marked unthriftiness. The limbs show abnormalities—pasterns are straight and calves tend to stand up on the toes. Joints, particularly those of the hind limbs, are "knobby" as a result of bony prominences. These clear up as the animal gets older (1½ to 2 years). Diarrhoea and signs of anaemia are commonly noted. With increasing age the animals grow very slowly and have a very stunted, undeveloped, and unthrifty appearance. On some holdings they cannot be reared into profitable members of the herd and are destroyed. Maximum size is not attained in adults on the worst affected properties and each successive generation tends to be smaller in frame.

3. *Results of Feeding Mineral Supplements.*

During the past three seasons experiments to determine the effects of regular feeding to milking cows of mineral supplements comprising copper alone or in association with other minerals* have been carried out on the two properties referred to above. In each case a group of cows receiving identical general treatment but no mineral supplements (= control group) was included.

The results have shown definitely that copper alone prevented any occurrence of anaemia. Cows in groups receiving copper appeared to maintain better health than those not receiving any. The addition of other minerals to the copper did not appear to benefit the animals in any way.

Cows receiving adequate copper supplement maintained normal blood copper values.

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*Cobalt, Zinc, Manganese, Nickel, Iron.

Elliot, H. G. (1939).—Departmental report.

Bennetts, H. W., and Beck, A. B. (1941).—"Studies of Copper Deficiency of Sheep in Western Australia"—Unpublished data.

Unfortunately in no instance did "falling disease" occur in the experimental herds so that it was impossible to relate the occurrence of "falling disease" to copper deficiency under experimental conditions.

Denmark lick has been widely used throughout the "affected" area. Data from a large number of properties, many of which have been under close observation for several years, clearly indicate that this lick has been responsible for marked improvement in the health and production of the herds including prevention of the temporary sterility referred to.

No cases of "falling disease" have been reported in cows receiving an adequate quantity of this lick, *i.e.*, not less than 2 oz. daily, although in some instances the disease has occurred in the naturally less susceptible "dry" cows, in the same herds, which have not been given the supplement.

In view of the experimental findings referred to above it would appear reasonable to attribute the beneficial effects of this lick to its copper content (0.6 per cent.) alone, although it is possible that other minerals, contained in it, may have had a contributory effect.

There is strong circumstantial evidence that copper deficiency is one factor predisposing to "falling disease" and in the light of information available it is reasonable to recommend the use of copper containing supplements, notably Denmark lick, to control both the direct manifestations of copper deficiency and an apparently associated condition "falling disease."

It would appear probable that copper salts alone would be equally effective, but, in absence of more complete experimental evidence, their use cannot be recommended with complete confidence.

Elliott (1939) has shown that topdressing with copper compounds has improved pastures on affected properties, notably in regard to the re-establishment of subterranean clover which has "stalled" and been replaced by drooping flowered clover.

Grazing on copper topdressed pastures would undoubtedly benefit the health and development of herds in these areas.

Bennetts and Beck (1941) working in another copper-deficient area, Gingin, have shown that the copper content of mixed pastures may be raised to "good" levels by topdressing with bluestone and that sheep maintained on such pastures show no evidence of copper deficiency and exhibit optimal development.

An experiment now in progress at Jindong is designed to determine the effects of copper topdressed pasture on the growth of calves. The relationship of copper deficiency to the occurrence of falling disease is being investigated further.

SUMMARY.

1. The cause of "falling disease" has not yet been determined. It has been shown, however, that a very low copper status of pastures and animals is a constant association.

2. There is strong circumstantial evidence that copper deficiency is one factor predisposing to the occurrence of "falling disease" but the experimental evidence is still incomplete.

3. It has been shown under experimental conditions that a "pure" copper supplement prevents anaemia and other manifestations of copper deficiency exhibited by cows in the "affected" area.

4. The use of a copper containing lick (Denmark No. 1) has resulted in a marked improvement in the health and production of treated herds. Its use in adequate quantities has apparently prevented the occurrence of "falling disease." The beneficial results are attributed to its copper content, but the use of this complex lick is still recommended pending further experimental inquiry. The dose advised is 2 oz. daily.

Tobacco Seed-bed Management.

A. SHARP, Tobacco Adviser.

INTRODUCTORY.

The provision of an adequate supply of well grown healthy seedlings from about the end of September onwards is one of the most important factors in successful production of tobacco leaf. The early part of October is the ideal time for planting out seedlings in the field in the Manjimup district. By that time, most of the cold weather is over and the ground has warmed up sufficiently to permit of fairly rapid growth, while in a normal season sufficient rain may still be expected to enable the plants to make good growth before the hot dry summer weather sets in. It is true that in a few favoured situations on well sheltered, moist land late planting has been quite successful but there is no doubt that, for the average tobacco grower, early October planting is the ideal to aim at.

Unfortunately, the cold, wet weather usually experienced in the Manjimup district during the early spring makes the provision of transplantable seedlings at this time almost impossible unless precautions are taken to protect seed-beds from the ill effects of cold weather, frost, excessive rain and disease. Formerly it was a common practice to plant fairly large areas of seed-beds in the open, and to leave them to take their chance, in the hope that, although some of them were almost sure to be a failure, sufficient would survive to plant the area required. It is now generally admitted by tobacco growers that this method is obsolete.

A number of growers have adopted the practice of having their seedlings grown for them in districts where the weather is milder than at Manjimup, the metropolitan area being popular for this purpose. While seedlings can be raised in the open there earlier than farther south, the practice is open to certain objections, the most important of which is the risk of importing disease into the tobacco-growing districts. For instance, it is well known that eelworm (*Heterodera marioni*) is widely distributed in the soils around Perth. This nematode is a serious pest of tobacco in the Eastern States, and in Queensland it is recognised as one of the principal causes of low yields of leaf. Until the 1936-37 season, eelworm was unknown in the Manjimup district, when unfortunately it made its appearance in a small portion of one tobacco crop. It may be regarded as inevitable that continued importation of large quantities of tobacco seedlings from the infected soils of the metropolitan area will lead before very long to the widespread appearance of this pest in the South-West. The careful grower,

therefore, will do his utmost to produce sufficient seedlings for his requirements on his own farm, even at some expense, rather than run the risk of introducing disease from outside.

The alarming increase in the dreaded seed-bed disease Downy Mildew, generally known as "Blue Mould," has rendered the necessity for the most careful seed-bed management more imperative than ever. The only effective method evolved so far for controlling this disease is by the use of benzol in covered seed-beds, and it is fortunate that the covering necessary for this treatment fulfils also the purpose of protecting the seedlings from cold, wet weather, frost, and to some extent at least, from insect attack, and stimulates the plants to more rapid growth, thus permitting earlier planting out than is possible with open seed-beds.

AREA OF SEED-BED REQUIRED.

The first question to be decided by the grower is the area of seed-bed he will have to sow. It is possible to grow up to 1,000 vigorous tobacco seedlings per square yard of seed-bed. If more than this number be permitted to grow, they tend to become spindly and weak. A reasonably successful seed-bed should carry an average of at least 700 plants per square yard. The number of seedlings required per acre varies from about 5,000 to 7,000 according to spacing. It will be seen, therefore, that ten square yards of seed-bed should yield at least sufficient seedlings to plant one acre, but it is usual to allow a margin over this in case any replanting may be necessary owing to insect attack in the field, etc. Twelve square yards of seed-bed for each acre to be planted may be taken as the safe minimum.

SELECTION AND PREPARATION OF SEED-BED SITE.

The seed-bed should preferably be established on rich, well-drained sandy soil. Although very rich soil is not suitable for the tobacco crop in the field, the most rapid and vigorous seedling growth is obtained in rich, heavily manured soil, and there is no danger of such soil in the seed-bed affecting the quality of the leaf from the mature plant. Heavy soils are not suitable, as these tend to form a crust on the surface which is detrimental to seedling growth.

The site should be open to the east and north so as to allow the maximum of sunlight to gain access to the beds, but it should be sheltered from the south and west.

It should be selected in autumn, and dug over or ploughed thoroughly in May, after the weed seeds have germinated, and be kept entirely free from weed growth throughout the winter. A sufficient area should be turned over to permit of at least five or six yards of cultivated soil all round the seed-beds. The advantages of thus fallowing the soil for a month or two before sowing are that the soil is sweetened, weed growth is killed, and any pests in the soil, such as red-legged earth mite, are starved out. The strip of bare soil round the beds serves to protect them from invasion by red mite, etc., from surrounding areas.

CONSTRUCTION OF SEED-BEDS.

The construction of the beds should begin early in July. They may be made any convenient width, say from three feet to four feet six inches, and any length according to requirements. If very long beds are constructed, however, it is recommended that they be partitioned off in lengths of about 30 to 40 feet in order to avoid the risk of currents of air dispersing the benzol fumes to be used later for the control of Downy Mildew.

The frame surrounding the seed-bed should be made of jarrah boards. Face cuts, which are obtainable cheaply from the saw mills, are quite suitable. Bush timber is not very satisfactory for the purpose.

There are several alternate designs which may be used. Probably the best one—which is also the most expensive—is to construct a wooden frame 15 inches high along the back of the bed and six inches high along the front, with sloping ends. Wooden sashes are then made to fit closely over the top. These are made of 3in. x 1in. timber, and may be up to ten feet or so in length. They may be made entirely removable, or, preferably, hinged at the back, so that they can be propped open during fine days. The covering material is tacked on to these sashes. Figure 1 is a sketch of this type, showing one sash open and part of another closed.

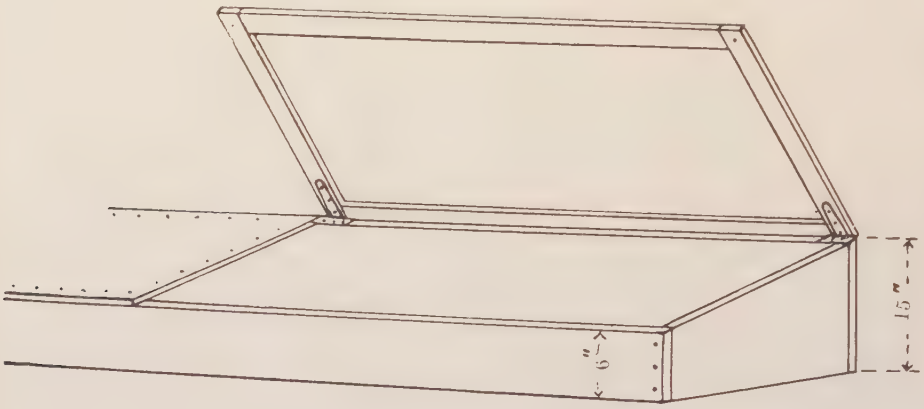

FIG 1

Another type, which requires rather less timber, consists of a wooden frame, about six inches high, all round the bed. A length of fencing wire is stretched tightly along the centre line of the bed, supported every ten feet or so by a short post. This wire should be six to nine inches higher than the top edge of the frame. The calico cover is tacked down along one side of the frame and is brought over the wire and tied down to the other side. The ends are filled in with shaped timber. When closed, this type has the appearance of a rather flat-roofed tent. To uncover, the front and ends are untied and the calico rolled up.

The principal advantage of the first type described is that the sashes can be easily and quickly handled when opening and closing the beds, and the covering is never rolled up and is therefore less liable to discolouration.

COVERS.

The cheapest effective covering material for seed-beds is unbleached calico, and experimental work has been carried out at Manjimup with various treatments for water-proofing and preserving this material. It was early discovered, however, that there was no necessity for the cover to be absolutely waterproof provided that it was stretched tightly over the bed and had sufficient slope to shed the rain. As most proofing materials, such as linseed oil and paraffin wax, have a definite tendency to discolour or rot the fabric, these are not now recommended. Ordinary unbleached calico without any treatment has been found quite satisfactory, both from the point of view of growth of seedlings and retention of benzol gas within the bed. The calico can be made to last for

two or more seasons without undue discolouration due to fungal growth if it is immersed for one hour in a solution of a proprietary preparation known as "Shirlan WS." One lb. of this substance to ten gallons of water is the strength recommended. On removing, the calico is wrung lightly and hung up to dry. Allowance should be made for shrinkage if the calico is to be cut before treating.

More rapid growth of seedlings can be obtained by using a proprietary glass substitute known as "Windolite," instead of calico. This material consists of translucent cellulose reinforced by flywire. It possesses the property of conserving warmth in the bed to a greater degree than does calico, and experiments extending over several seasons have shown that seedlings raised under it are ready for transplanting about a fortnight earlier than those in adjoining beds raised under calico. Its principal disadvantage is its high initial cost. With reasonable care, however, it should last at least four or five seasons, so that, taken over a period of years, the cost is not excessive.

SOIL PREPARATION.

Having constructed the frame, the soil is worked to a fine tilth, and a complete fertiliser, at the rate of about one pound to the square yard, thoroughly worked into the top three or four inches. Potato Manure "E" or Standard Tobacco Fertiliser each contain nitrogen, phosphoric acid and potash, and are suitable for the purpose. The surface of the soil is then carefully levelled. It should be several inches above the level of the surrounding soil to ensure good drainage.

SOWING THE SEED.

An ounce of tobacco seed contains approximately 300,000 seeds, and in the case of good seed, will be sufficient for at least 100 square yards of seed-bed. It would be extremely difficult to distribute such small seed evenly without using a suitable medium, and the usual practice is to mix it thoroughly with sifted wood ashes, fine sifted sand or fertiliser. If the last-named is used, it should be sown immediately after mixing, as the fertiliser is liable to injure the seed. A method which the writer has used successfully is to thoroughly mix one level teaspoonful of seed with about one pint of wood ashes, and to distribute the mixture over ten square yards of seed-bed. The ashes show clearly where distribution has been effected.

Having sown the seed, the soil is compacted by means of a light roller or by pressing with a piece of board in order to bring the seed into intimate contact with the soil particles. The seed should not be raked in as this would cover it to too great a depth. It is advisable to give the bed a light watering immediately after sowing. This should be done with a watering can fitted with a very fine rose, otherwise there may be a tendency to wash the seed off the bed. Great care must be taken not to allow the surface of the seed-bed to become dry until germination has taken place. This can be expected in about three or four weeks in the case of July sowing. During very cold weather, the writer has hastened germination somewhat by watering daily with slightly warmed water. It is suggested that successive sowings at intervals of a week or more be made so as to ensure a continuous supply of seedlings during the transplanting season.

CARE OF SEEDLINGS.

When germination has taken place, the seed-bed covers should be opened on fine days and kept closed during the night and on cold, wet days. As soon as individual plants are discernible, they should be thinned out if necessary. About

one plant per square inch is quite thick enough. Overcrowded seed-beds are most likely to be attacked by various fungal diseases to which tobacco seedlings are susceptible. One of the more important of these is known as "Damping-off." It is caused by any of several fungi which produce a rot in the stem of the seedling near the surface of the soil. Quite frequently growers have reported that although their tobacco seed germinated well the seedlings simply disappeared shortly after germination. In all probability this was due in many cases to damping-off. Where seedlings begin to die off in patches, the grower is recommended to apply Cheshunt mixture immediately.

Cheshunt mixture is made by thoroughly mixing together two parts by weight of powdered bluestone and eleven parts by weight of fresh powdered rock ammonia (Ammonium carbonate). The dry mixture is placed in a tightly stoppered glass or stone jar for at least 24 hours before using.

To use, take one ounce of the above mixture and dissolve in two gallons of water in a copper or pitch-lined vessel. Water the affected seed-bed with the solution until the soil is nicely moist, then wash the solution off the leaves of the plants with an amount of pure water equal to the quantity of Cheshunt mixture used. This should be repeated twice a week until the plants are about a month old. In addition to its action as a fungacide, Cheshunt mixture has been observed to stimulate the growth of seedlings, due, probably, to the rock ammonia acting as a nitrogenous fertiliser.

CONTROL OF DOWNY MILDEW (BLUE MOULD).

Downy mildew is by far the most serious disease affecting tobacco in Australia. It is fully discussed in Leaflet No. 486 issued by the Department.

Experience in Western Australia so far has indicated that this disease seldom attacks seedlings less than three weeks old, but from then onwards it is necessary to afford protection by introducing benzol to the seed-beds.

The method adopted by the writer with complete success is to place round 2-ounce tobacco tins at regular intervals along the seed-bed, and to fill these with benzol every evening, just before closing the covers for the night. On opening the covers the following morning, that portion of benzol remaining unevaporated is poured back into the container. During stormy weather, the covers are kept closed day and night, the beds being opened only long enough to replenish the supply of benzol.

The tins for holding the benzol are set up on wire stands about three inches above the surface of the soil, and are spaced so that there is one square inch of evaporating surface to every square foot of seed-bed. Any kind of tin will do, such as tobacco tins, cut-down jam tins, etc., provided, of course, they do not leak. They should not be more than 1½inches deep, and preferably not more than about 5 inches in diameter.

The following table gives the approximate area of evaporating surface of benzol contained in round tins of given diameters.

Diameter of Tin.	Area of Evaporating Surface.
2 inches.	3 square inches.
2½ „	5 „ „
3 „	7 „ „
3½ „	9½ „ „
4 „	12½ „ „
4½ „	16 „ „
5 „	19½ „ „

From this, the grower can calculate how many tins of given diameter will be required for any seed-bed. For instance, if it is desired to treat a seed-bed 30 feet long by 3ft. 6in. wide, and the tins to be used are 3 inches in diameter, each tin, having a surface area of 7 square inches, will protect 7 square feet of seed-bed. The total area of the bed is (30 × 3½) = 105 sq. ft. Therefore the number of tins required is 105 divided by 7 = 15 tins. The tins should preferably be placed in two rows along the bed, each row about nine inches to a foot from the edge of the bed and the tins staggered as shown in fig. 2.

A concentration up to 50 per cent. greater than that recommended here has been found to be quite harmless to tobacco seedlings, but some injury may be done if such a concentration is exceeded.

A number of substitutes for benzol have been tried out experimentally at Manjimup, but, although some of these have given a fairly high degree of control, none has been entirely successful under all conditions. Growers are therefore recommended to be sure that they use genuine benzol only. It may here be stated that genuine benzol is defined as being the portion of the light-oil distillate of coal tar with initial and final boiling points at 70 deg. C. and 98 deg. C. respectively, and having a specific gravity of 0.882 at 60 deg. F.

The amount of benzol consumed in the seed-beds will vary somewhat according to weather conditions and the type of seed-bed, but under average conditions a consumption of about one pint per square yard of seed-bed per week may be expected.

Benzol in the liquid state is absolutely fatal to seedlings, therefore it is important to avoid spilling or splashing when filling the tins. It is also highly inflammable and should not be handled near an open flame or lighted cigarette.

While it is advisable to cover seed-beds during stormy weather, care should be taken not to keep covers on unnecessarily, especially within a week or two of transplanting. Seedlings which have been shaded too much tend to become soft and spindly, and do not transplant well. Covers should be closed every night without fail, but should be kept open as much as possible during the day. A few showers will not damage the plants, and the rain on the foliage will not induce an attack of downy mildew, as some growers believe, provided that benzol is used as directed every night.

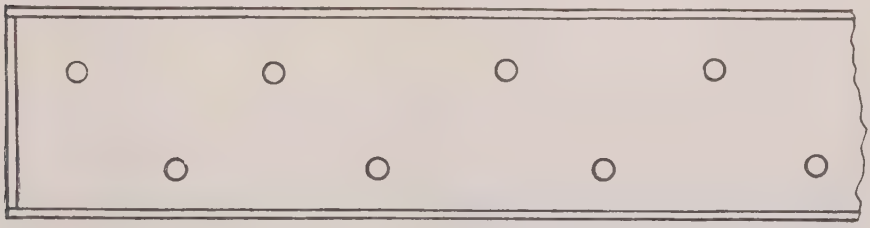

FIG 2

Should the seedlings not be making satisfactory progress, the application of liquid manure may be resorted to. A small handful of nitrate of soda to every four gallons of water may be applied once or twice a week to stimulate growth. It is important not to make the solution stronger than this otherwise the plants may be injured. Better still is an application of a very weak solution of fowl manure, if available.

TRANSPLANTING.

The seedlings are ready for transplanting when about four inches high. Before pulling them, the seed-bed should be thoroughly watered, as the seedlings can be lifted from loose, moist soil with the minimum of damage to the roots. When pulling, the two largest leaves should be held between thumb and forefinger, above the growing tip of the plant. It is important not to injure the stem or growing point, but a little bruising of the outside leaves does not matter as they will be primed off before harvest in any case.

In conclusion, the grower who, by careful management of his seed-beds, is able to plant up his fields with healthy, vigorous, well-grown seedlings, will normally have to do little or no replanting. The result will be even growth in the field and even maturing of the leaf. The importance of this latter point cannot be stressed too strongly, as the harvesting of leaf of even maturity is essential if success is to be obtained in curing.

Pregnancy Toxaemia of Ewes.

C. R. TOOP, Senior Veterinary Surgeon.

Introduction.

With the approach of the lambing season, losses resulting from pregnancy toxaemia are frequently sustained by sheep breeders. This disease has a world wide distribution and has been described under a wide variety of names, the most common of these probably being "twin lamb disease," "pregnancy disease of ewes," and "pregnancy paralysis." The disease, however, might more appropriately be termed ketosis of pregnant ewes, due to the fact that there constantly occurs in the blood of affected animals an accumulation of toxic substances known as ketone bodies, which are responsible for the development of the symptoms and the ultimate death of the animal.

Pregnancy toxaemia affects ewes which are heavy in lamb, the losses resulting from it being almost wholly confined to the last three or four weeks of pregnancy. Few affected animals recover after the symptoms have become well established. Ewes carrying twin lambs or triplets are most frequently affected, hence the popular name, "twin lamb disease." Ewes carrying single lambs do, however, quite often become affected. In such instances the lamb may be found to be abnormally large in size. The outstanding feature at post-mortem is the extremely fatty appearance and pale yellow colour of the liver. Although the exact cause of the disease has not yet been determined, there is abundant evidence to show that it is nutritional in origin. Evidence obtained, both experimentally and from the field, overwhelmingly supports the opinion that it is associated with under-feeding and loss of condition during late pregnancy.

In Western Australia pregnancy toxaemia occurs throughout the agricultural districts, but it has not been reported from the pastoral areas. The annual losses resulting from it are extremely variable. Whilst during some seasons mortalities may be numerous and widely distributed, in others, for reasons not well understood, they may be of comparatively rare occurrence. Similarly the losses occurring in individual flocks are subject to considerable fluctuation. In some cases they may be small and insignificant. In others they may reach serious proportions and in isolated instances have been known to approach the high figure of 50 per cent.

The symptoms.

Ewes of all ages and breeds are susceptible to the disease. Mature ewes, however, are most frequently affected, due to the greater tendency towards twinning or multiple pregnancies in such animals. The losses are almost entirely confined to the last three or four weeks of pregnancy. The disease may, however, appear as early as six weeks before the due date of lambing. The affected animal appears dull, cease to feed, and becomes separated from the flock. It appears dazed and stupid and pays little heed when approached. It is often possible to approach within a few feet of the animal or even to touch it before it will attempt to move away. When so disturbed the animal moves off slowly and aimlessly, proceeding for a short distance only before again coming to a halt. In many affected animals there is complete blindness, while in others the vision is seriously impaired. Grinding of the teeth is an almost constant symptom. When driven affected ewes frequently show a somewhat stiff, unsteady gait behind and may collapse after proceeding a short distance, falling to the ground sometimes with the hind limbs extended behind the body. From this position the animal is usually unable to regain its feet without assistance. Finally the ewe goes down and is unable to rise, lying in a comatose condition until death occurs. Affected animals may linger for a few days to a week or more from the first appearance of the symptoms. Few affected animals recover, the mortality rate being in the vicinity of 90 per cent. Should lambing occur in the early stages recovery is possible. When, however, the symptoms have become well advanced lambing does not influence the course of the disease and recovery at this stage is unlikely. Ewes which have already lambed do not become affected.

During the course of some outbreaks of pregnancy toxaemia certain of the ewes, while remaining apparently healthy themselves, may give birth to dead or weak lambs. This occurrence is considered by some observers to be a further manifestation of the disease.

The post-mortem appearances—fatty liver.

At post-mortem the principal and frequently the only abnormality will be found in the liver. This organ, as the result of a heavy infiltration with fat, will appear somewhat enlarged and characteristically pale yellow in colour. Sometimes similar though much less marked changes occur in the kidneys, which may in consequence appear paler in colour than normal. In a high percentage of the cases two or more lambs will be found in the uterus.

The predisposing factors—under-feeding.

Two directly opposite views have been expressed concerning the factors which may predispose to the disease. On the one hand the opinion is held that the disease is associated with overfatness and lack of exercise during late pregnancy, and on the other that it is due to under-nutrition and loss of condition during this period. Until fairly recently the former view was generally accepted. It now finds little support, neither being borne out by the field nor the experimental evidence. Experimentally it has not been found possible to produce the disease by feeding pregnant ewes to overfatness, and at the same time confining them in pens in which they have been able to obtain little or no exercise. Moreover when fat ewes become affected in the field, it is often possible to find evidence of underfeeding, though this may have been suddenly imposed and of comparatively short duration.

The opinion that the disease is associated with under-feeding and loss of condition during late pregnancy is on the other hand strongly supported by both

field and experimental evidence. Under experimental conditions the disease has been reproduced by continued under-feeding, or by subjecting the ewes to a period of sudden starvation. Furthermore, in such cases there is evidence of an accumulation of ketone bodies in the blood and urine of the same order as that which is found in the naturally occurring cases of the disease. Ketone bodies cannot be demonstrated in the blood of fat ewes which are receiving an adequate ration.

Under field conditions outbreaks of pregnancy toxaemia may occur when forward in lamb ewes are trucked long distances by rail and are, as a consequence, completely deprived of food for long periods. Similarly, in countries where the climatic conditions are severe mortalities are frequently reported following snowstorms. Here again the ewes are subjected to a period of enforced starvation owing to the fact that the pasture has become covered with snow and thus rendered inaccessible.

Where mortalities resulting from the disease have been investigated in this State it has generally been found that the feed available has not been adequate, and the ewes have been found to be in only fair condition. Sometimes their condition has been poor. One mortality can be recalled which involved the loss of nearly 50 per cent. of a flock of full mouthed ewes. The animals were in extremely low condition, the paddocks were bare and hand feeding had not been practised.

Under West Australian conditions, unless measures are taken to prevent it by hand feeding, it is almost inevitable that ewes will suffer from under-nutrition during the latter half of pregnancy, and that this will become progressively more acute as lambing approaches. In the majority of flocks lambing will be timed to commence during May, being preceded by a prolonged, and for the most part, dry summer season. During this period, which extends from October to May, the grazing available steadily deteriorates, becoming reduced in quality and often in quantity. It is quite inadequate to maintain the condition of the flock, and unless hand feeding is practised on an adequate scale, loss of condition is certain to result. Pregnancy toxaemia commonly occurs under such conditions.

During certain seasons widespread mortalities have occurred following upon the opening autumn or early winter rains, especially when such rains have fallen at a time when lambing is about to commence, or when the earlier lambs have already been dropped. For several weeks following these rains a period of acute feed shortage usually exists. The available dry feed is frequently spoiled and the sheep walk the paddocks eagerly seeking the short and scanty green shoots. Until the green feed becomes well grown, under-nutrition together with loss of condition is inevitable. It has been observed that mortalities occurring under these circumstances have ceased when the green feed has become plentiful or when it has been possible to turn the flock on to an early sown green crop.

When the disease appears amongst ewes which are in good condition and are being adequately hand fed, the possibility cannot be overlooked that certain of the less aggressive animals do not succeed in obtaining their full share of the ration and may in reality be falling off in condition

It thus becomes apparent that ewes, whether in fat, poor or indifferent condition, may become affected with pregnancy toxaemia if they are underfed or are suddenly deprived of food during advanced pregnancy.

Cause.

The exact cause of the disease has not been determined. In all affected ewes, however, the presence of toxic ketone bodies may be demonstrated in the blood and urine by chemical means. Moreover, the blood sugar falls to a level far below normal. It is suggested that the development of ketosis is associated with a low

carbohydrate intake which occurs when the ration is inadequate. Carbohydrates are represented by such substances as starches and sugars, and are the main source from which the animal derives its energy requirements In the animal body carbohydrate is stored in the liver in the form of glycogen. In the pregnant ewe this reserve store of glycogen is drawn upon to meet the increased requirements of the mother and of the rapidly developing lamb which stores glycogen in its own liver in quite large amounts. In a twin pregnancy the demands upon the glycogen reserves in the liver of the ewe are specially heavy, and they consequently become depleted and sink to a low level.

If in addition to this the carbohydrate intake is low as the result of underfeeding, the ewe is forced to draw upon its fat reserves in order to obtain its energy requirements. Fat is transported from the fat depots of the body to the liver where the first stage in its combustion or oxidation takes place. The liver in consequence, becomes heavily infiltrated with fat. When fat is completely burned or oxidised in the body, the end products are water and carbon dioxide, which are excreted and produce no ill effects. When, however, there is a deficiency of carbohydrate, the oxidation of fat cannot proceed to completion. The process becomes arrested at an intermediate stage, wherein the fat has become converted into products known as ketone bodies which accumulate in the blood and make their appearance in the urine. Ketone bodies possess toxic properties and are acid in reaction. The symptoms observed in pregnancy toxaemia are attributable to their presence.

It must, however, be emphasised that the actual cause of the disease still remains rather obscure, and that certain of its features still require an explanation. Quite a number of theories have been advanced to account for its occurrence, but further research will be necessary before a clear understanding of the condition is finally obtained.

Treatment.

No satisfactory method of treatment is known and after the symptoms have become well established, recovery rarely occurs. Good results have occasionally been claimed from the administration of sugar or molasses at the rate of 1 lb. to 1½ lbs. daily, dissolved in water and given as a drench and from the intravenous injections of solutions of the sugar glucose. The results of treatment however, are generally so unsatisfactory that it must, in the majority of cases be regarded as hopeless.

Prevention.—Supplementary feeding.—The prevention of the disease appears to be largely a matter of feeding and management. Under-feeding, together with loss of condition, is the principal predisposing factor, and steps must be taken to prevent this occurring during late pregnancy. To ensure that ewes will at least maintain their condition during this period, hand feeding will be necessary on the great majority of properties. The period at which hand feeding should commence will depend upon the amount and quality of the grazing available in the paddocks and the condition of the sheep and will call for a good deal of discretion on the part of the individual sheep owner. In general, however, hand feeding should commence not later than eight weeks before the due date of lambing, with a tendency towards increasing the ration during the last month. The supplements available for hand feeding will generally consist of wheat, oats, barley, chaff, hay, and occasionally silage. Experiments carried out by the Animal Nutrition Officer of this Department have shown that, with very poor grazing available, prognant ewes are more than able

to maintain their condition on any of the following daily rations:—½ lb. wheat, ¼ lb. wheat plus 1½ lbs. silage, or ¼ lb. wheat plus ½ lb. chaff. From this information the recommendation may be made that hand feeding be commenced in early or mid-summer with a daily allowance of ¼ lb. of wheat per head increasing to ½ lb. per head daily about six weeks before lambing is timed to commence. A daily addition of ½ lb. hay or chaff to the grain ration will be advisable if the grazing is scanty. Barley, which is similar in feeding value to wheat, should be fed in the same amounts. The feeding value of oats is three-quarters that of wheat, and where oats are being fed, an adjustment will need to be made on the basis that 100 lbs. of oats will replace 75 lbs. of wheat in the ration. Chaff, hay or silage alone will not provide the full requirements of the animal. Although no definite scale can be laid down, the above figures will serve as a guide to sheep breeders concerning the amounts of the different food supplements it will be necessary to make available. These rations should be sufficient to meet requirements during normal seasons but under drought conditions they would probably need to be somewhat increased during the last month of pregnancy in order that losses might be avoided. Quite apart from the aspect of disease prevention however, feeding on this scale is desirable if the flock is to be carried through the summer and autumn months in satisfactory condition.

Green Crops.—The value of young nutritious green feed as a preventative has long been recognised, and when available it probably provides the most effective means of prevention and control. Early sown green crops will be found of especial value in preventing those mortalities which may occur during the period of feed scarcity which follows the opening rains. Such crops will usually be well grown, and in a fit condition to allow of grazing quite a considerable time before the natural pasture is sufficiently advanced to fully satisfy the requirements of the sheep. The growing of crops for early green feed is a procedure which might with advantage be more generally adopted as a precautionary measure. In any case, it is a sound farming practice which will later provide the rapidly growing lambs with an abundance of feed.

Exercise.—Almost all of those who have investigated the disease are agreed upon the beneficial effects of exercise. In order that this may be obtained droving in some instances will be necessary, in which case the flock should be travelled for a distance of a mile daily. Hand fed sheep will be compelled to take exercise if the feed is distributed in a different part of the paddock each day, or if conditions are so arranged that it will be necessary for them to travel to water.

Periods of sudden starvation during late pregnancy, such as would result from trucking or yarding for unduly long periods, should be avoided.

Measures necessary to control an outbreak.

When an outbreak of pregnancy toxaemia occurs, the application of the preventive measures detailed above will be necessary in order to check the mortality. In most, if not all outbreaks, evidence of under-nutrition will be found, and this must be overcome. Hand feeding on the above recommended scale should be commenced immediately, or if the scale of feeding has been found inadequate, it should be increased to at least that level. Better still, the flock should be turned on to a young green crop if this is available. Daily exercise should be combined with these measures. If no evidence of under-feeding can be discovered, exercise alone should suffice.

Fertilisers—Additional Registrations.

Name of Fertiliser.	Reg. No.	Brand.	By Whom Registered.	Nitrogen (N) as				Phosphoric Acid (P_2O_5) as				Potash (K_2O) as		Cash Price per ton on Rail at Works or Perth.
				Nitrate.	Ammonia.	Blood and Bone.	Bone-dust.	Water Sol.	Citrate Sol.	Acid Sol.	Total.	Sulphate.	Muriate.	
				%	%	%	%	%	%	%	%	%	%	£ s. d.
Bone Fertiliser	114	Falls	W. H. Logie	....	....	....	3·00	....	....	....	18·00	....	....	W 8 0 0
*Batsos	115	Bat	Batsos Trading Co.	....	....	....	....	·24	1·00	·76	2·00	....	....	P 7 15 0
Blood and Bone	116	Albany Freezing Works, Ltd.	Albany Freezing Works, Ltd.	.	.	6·00	. ..	....	....	....	12·00	. ..	....	W 10 0 0
Bonedust	117	do. do.	do. do. do.	....	....	....	3·50	....	....	....	22·00	....	....	W 8 0 0
Castor Meal Fertiliser .	118	Sweetsoil	Westralian Farmers, Ltd.	. .	.	. ..	4·50 (as castor meal)	....	2·25	.	2·25	·75	....	Price on application.
Blood and Bone	119	Pannifex	Paterson & Co., Ltd.	....	....	6·00	....	....	5·00	7·00	12·00	....	....	P 12 5 0
Do.	120	Hassells	do. do.	....	....	5·00	....	....	7·00	7·00	14·00	....	....	P 12 5 0

* Contains trace Nitrogen and Potash. W Price per ton at Works. P Price per ton at Perth.

ERRATA :

With reference to the list of registered fertilisers published in the March, 1941, issue of this Journal, the following corrections of the prices per ton at Works should be noted :—

"Eclipse" Bone Dust—£7 15 0.

"Eclipse" Blood and Bone—£10 5 0.

"Robb's" Blood and Bone"—£10 0 0.

Pig Premises.

M. CULLITY, Acting Superintendent of Dairying.

Introduction.

The problem of providing adequate accommodation for his pigs is as important to the farmer as that of feeding and breeding. Profitable returns cannot be expected unless the pigs are healthy and comfortable.

Although consideration has to be given to the question of breed, with the standardisation in this State to the Berkshire, Tamworth, and Large White, the real problem for the farmer in selecting his animals is one regarding the type which will be satisfactory in the market. Ample supplies of various types of feeding

Figure 1.
A type of bush shelter suitable for Wheat Belt conditions.

stuffs may be available, feeding methods may be studied and the farmer acquire some measure of skill in compounding rations, but this will be of little value unless the pigs are kept under conditions which will not cause any inefficiency in the utilisation of their feed.

Disease which so frequently plays havoc with a promising pig venture may be prevented, to a great extent, by observing certain rules of sanitation.

The type of accommodation required will depend upon the system of pig-raising followed. In Western Australia there are two different sets of conditions. The wheat farmer—with large supplies of grain available supplemented with purchases of meatmeal—has little necessity to bring his feeding operations to any particular part of his property. Under these conditions a number of pig-proof paddocks can be made available with various types of shelters. The obvious desirability of convenience suggests that these paddocks be arranged on a plan which will facilitate the handling and feeding of the pigs. In the dairying areas, however, the tendency is to congregate the pig premises on to a smaller area relatively close to the milking sheds. Frequently, conditions are very far from being satisfactory and inevitably lead to uneconomical utilisation of feed and promotes a tendency towards disease.

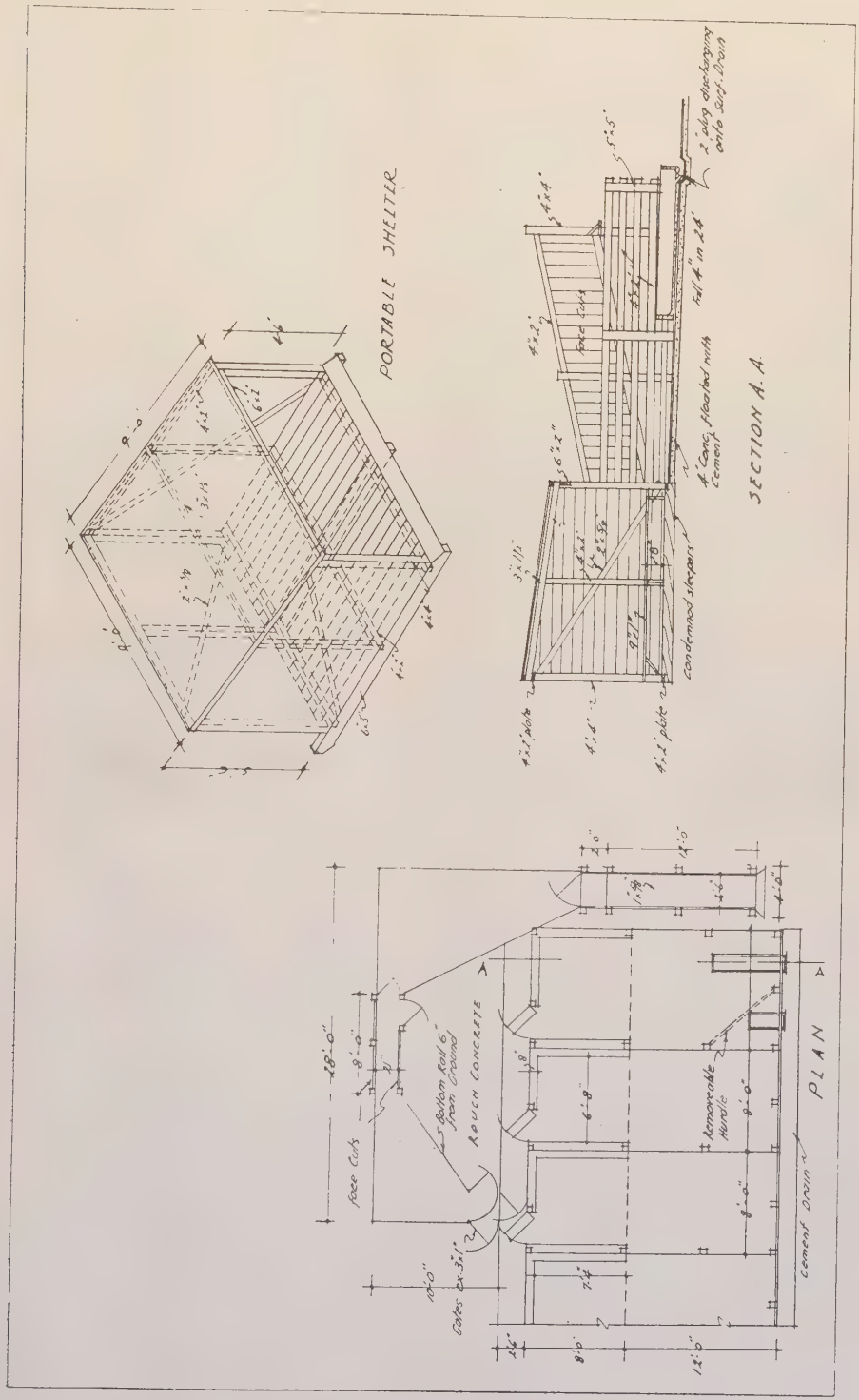

Figure 2.
Diagram of farrowing pens, drafting yard, and movable shelter.

There are certain well defined rules which should be considered before establishing a piggery--

1. *Location.*

It is necessary to bear in mind the size of the proposed operations. The site preferably should be on a gentle slope where drainage would be easy and adequate. Sandy soils naturally are more suitable than those with a large proportion of clay or where a hard subsoil is present.

It is suggested as a basis for working that not less than ½-acre per sow should be available. There also should be sufficient room should it be decided at any time to expand the operations.

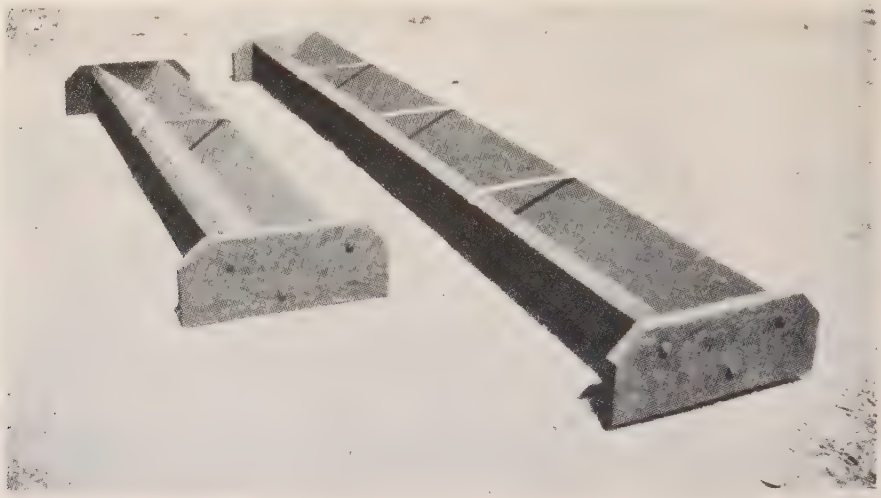

Figure 3.
Simple portable feeders, easily made on the farm.
[Queensland Journal of Agriculture.]

In the wheat belt the piggery naturally will be adjacent to the point of feed supplies and convenient for the feeder. In the dairying districts, as stated previously, it usually will be situated near the milking shed, and on a lower level to facilitate the conveying of skim milk in buckets or to allow of the laying of piping or of open guttering along which the milk could flow to the feeding point.

Under the provisions of the Health Act, a piggery must not be constructed nearer than 200 feet to a residence, dairy, or other premises wherein food is prepared for sale, nor less than 100 feet distant from any street or thoroughfare. This applies not only to the pens where the pigs are housed but to any enclosure in which the pigs may be allowed to run.

2. *Aspect of Sheds and Pens.*

An easterly or north-easterly aspect should be selected for the sheds and pens. This will allow sunlight to penetrate into the houses providing warmth and dryness. This is specially important in the areas of higher rainfall and in the winter months. In this position also the entrance to the pens is well protected from the force of the prevailing rain-bearing winds. In areas where strong winds from other quarters are experienced, it also is desirable to provide some form of breakwind.

Figure 4.
Movable shelters on pasture, Muresk Agricultural College.

Figure 5.
A woven wire mesh fence is very suitable for pasture paddocks.
[Miss D. Noon.]

3. *Type of Building.*

Satisfactory premises may be provided without undue expense but they must be comfortable, that is, dry and warm. Each yard and paddock should be provided with a draught-proof shelter, and it is a matter for the individual farmer to decide whether he will build shelters of sawn wood with iron roofs or whether he will utilise the materials that may be available on the farm. As a general rule, it may be stated that—providing structures are of a permanent type—there is no real object in incurring expense in order to make them elaborate. Bush timber for post and bearers, and straw or scrub providing the cover for the roof and sides, provide excellent shelters in the wheat areas. (See figure 1.) In the South-Western districts where a higher rainfall is experienced, this type of bush shelter is not as satisfactory. The conditions necessitate housing structures which will be proof against the rain and the seepage of large quantities of water through the soil.

In figure 2 is shown a design for farrowing pens suitable for these districts. These give access to a race leading to small paddocks.

Figure 6.

Sapling fences on the property of C. J. Browning, Kondinin.

4. *Farrowing Pens.*

The farrowing pens should not be less than eight feet long by eight feet wide, and they should be provided with a guard rail eight inches from the ground and projecting approximately eight inches from the wall. This rail will save the lives of many young pigs by preventing their being crushed by the mother when she is turning or otherwise changing her position. The floor of the farrowing pens should be of wood, either sound sleepers or preferably wooden racks over-lying a concrete base. A small concrete yard 12 feet long and the same width as the pen, is attached to each. At the far end of this yard, the feeding trough can be located either projecting through the wall or else being placed alongside a swinging hurdle. (See figure 3 "Convenience in Pig Farming," Journal of Agriculture, June, 1940.)

These arrangements permit feeding without having to force the pig back from the trough with the danger of bruising it.

Arrangements also can be made for a smaller trough inside a creep in the corner of the yard for the feeding of the young pigs. (See figure 13, "Pigs—Management and Feeding," Journal of Agriculture, December, 1940.) The use of this should be commenced when the pigs are approximately three weeks old. At this age

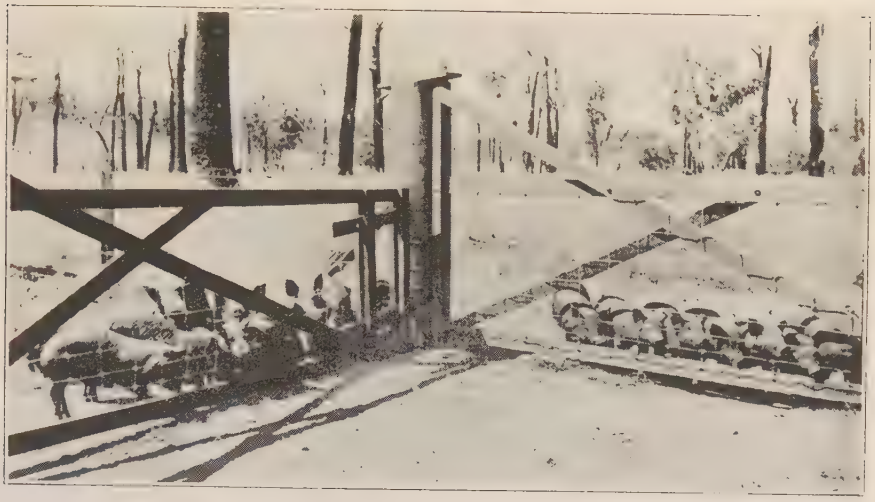

Figure 7.
These gates prove satisfactory for the smallest pigs.
[Miss D. Noon.]

Figure 8.
Cheap movable shelters.
[W. Nunn.]

they commence to forage a little for themselves. The necessity of promoting rapid growth in the suckers and weaners and until the pigs are about four months—in order that they may make ample bone and muscle—renders the creep method particularly valuable.

The concrete feeding troughs are built in at the same time as the floor. These are about nine inches high and 12 inches wide and are fitted with a drainage plug opening into a drain which runs along the length of the pens.

When feeding is carried out at different places from time to time, other types of troughs are necessary. Various kinds constructed of metal are available on the market, but probably the most simple for the average farmer is that which can be readily made on the farm and illustrated in figure 3.

However, where pigs are run in paddocks, the most efficient trough is that constructed of concrete on a concrete platform large enough to carry all the pigs that may be in the paddock at the time.

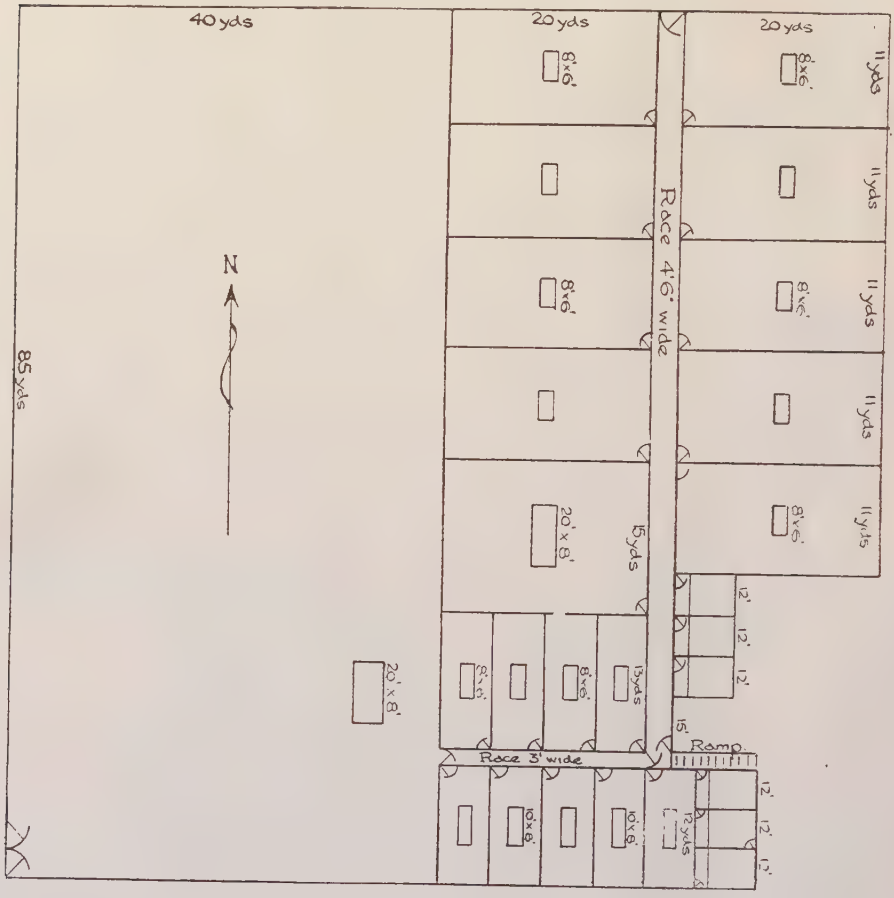

Figure 9.
Layout of Pigging—H. Blythe, Manmanning.

5. *Paddock System.*

The advisability of providing paddocks for grazing cannot be stressed too strongly. Even in areas where pasture may not be available, the animals will be happier and healthier when allowed the freedom of a large run. The old method of enclosing pigs in sties reduced their natural hardiness, their prolificacy, and their disease-resisting capacity. By contrast pigs reared and fattened in the open are usually healthy and profitable. The exercise obtained in the open also tends to promote the development of muscle which, of course, is the lean meat in the carcase.

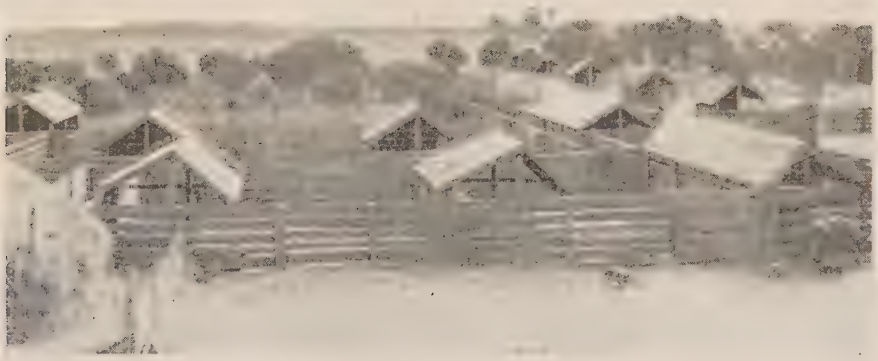

Figure 10.
General view of piggery—H. Blythe, Manmanning.

Figure 11.
View of race and ends of subdivision fences—H. Blythe, Manmanning.

The modern demand is for a carcase containing a large proportion of lean meat, and this is more readily grown under the paddock system than under the conditions of intensive sty feeding. The value of grazing also is considerable in the amount of young short sweet grass which is consumed.

It has been stated that, in addition to the minerals and vitamins which are obtained from grass, ample grazing eliminates the necessity for providing other protein supplements.

6. *Moveable Houses.*

Moveable houses frequently are necessary, particularly when pigs are run on the open or paddock system. A diagram of one is shown in figure 2, and illustrations of other types are in figure 4. All are built on skids so that they can be moved at will from paddock to paddock or to various points of the same paddock as would be necessary on soils which puddle easily. The essential details in these houses are the same as in the permanent sties, that is, they must have good floors, draught-proof walls, and rain-proof roofs.

Figure 12.

A concrete feeding passage with the ends of the troughs projecting through the fence. The end of the loading race can also be seen.

[Miss D. Noon.]

7. *Fences.*

The woven mesh fence is the most satisfactory. With ordinary netting, a barb wire at the bottom is required to prevent the pigs from rooting underneath and forcing the wire up. However, with the stronger mesh this is not required.

Figure 5 shows pigs held in pasture by a sound type of woven wire fence.

Other satisfactory fences are those constructed of palings or slabs sunk into the ground or of palings bound with interlacing wires.

The use of straight saplings as practised widely in the wheat belt is also satisfactory and economical. (Figure 6.)

8. *Gates.*

A problem that confronts many pig farmers is that of constructing a pig-proof gate sufficiently wide to serve all purposes for which a gateway may be required; for example, the passage of carts or large implements.

In figure 7 is shown an illustration of a gate constructed of a timber frame which has been covered with a strong woven wire. As the illustration shows, this proved efficient even for young pigs.

9. *Loading Ramp and Drafting Yard.*

The equipment of each piggery is not complete unless a means of drafting and loading pigs easily into the vehicles in which they will be taken to market is provided. (See figure 2.) The advantage of this should be obvious: the rushing and prodding that is associated frequently with the loading of pigs will be avoided as well as expenditure of considerable energy by the farmer and the danger of bruising the flesh of the animals.

Figure 13.

The electric fence can be used as a temporary means of feeding pigs in pasture.

10. *Feed Sheds.*

Very few store houses specially constructed to hold feed have been provided. The advantages of having a reservoir of grain close at hand needs no emphasis. This feed room probably is more useful in the wheat belt than in the dairying districts. In the latter areas the main food is provided from the dairy in the morning and evening, and storage for a few hours at most is required.

The installation of a tank at the piggery—which can be filled direct from the separator—has been stressed frequently, but, even under these conditions, particularly with the larger piggeries, a store room for grain is useful and may be rendered mouse-proof by using flat iron lining, etc. This should be situated close to the feeding pens.

11. *Water Supply.*

An adequate supply of water is essential. Pigs will consume relatively large quantities particularly in the hot weather. Where it is possible to give them proper attention, wallows are a great advantage in keeping the animals cool during the summer. Although the depression may not be large, it must be cleaned frequently and disinfected to reduce the possibility of disease being transmitted in dirty conditions. It is the possibility of spreading disease in this way that has caused

the use of wallows to be discouraged. A third reason why an ample supply of water is necessary is to enable the fattening and farrowing pens to be washed down frequently.

12. *Drainage.*

Some comment already has been made on the necessity of selecting a site on which efficient drainage may be obtained. Where a number of pens are situated together, a general drainage system has to be devised. Usually it is most convenient —as well as the means of keeping the pens relatively clean—to have the floors and yards sloping diagonally towards the entrance gate. In this way the movement of water and refuse is away from the shed and also from the feeding trough. A single drain running the length of the pens and extending some distance beyond will prove efficient in most circumstances.

Haricot Beans.

By G. St. Clair Fielden, B.A.

(Occasional Paper No. 6 (War), of the Imperial Bureau of Horticulture and Plantation Crops, East Malling, Kent, England. Price 1s.)

This Bulletin which supplied needed information dealing with the culture of haricot beans was compiled at the request of the Ministry of Agriculture, London, primarily to help those intending to grow haricot beans for private or commercial purposes. In addition it contains a brief account of work with the beans in the United States of America, Canada, and of experiments in England at Wisley, Cambridge and elsewhere.

In this time of war the high protein content of the haricot bean should make it a very valuable foodstuff either for human beings or stock. In view of the fact that the bean is grown extensively in U.S.A. it would seem that it could be grown as profitably in this country. More especially would this apply to the small white pea-bean types, that have the shortest growing periods, though in the warmer and more arid areas coloured or mottled varieties are preferred. Essential qualifications are:—

1. Capacity for being sown and ripened in about 120 days.
2. Dwarfness.
3. Hardiness.
4. Disease resistance.
5. Capacity to remain erect and hold the pods off the ground sufficiently to prevent weathering.
6. Non-shattering of pods before or during curing process, with ease of threshing by hand for the private grower.
7. Ability of seed to resist splitting during threshing.
8. Size, quality and colour "suitable to requirements of the canning trade."

From the canner's standpoint a high quality bean is one that can be baked before becoming dry or tough, uniform in size and colour, defect free, absorbing moisture uniformly, non-splitting and non-disintegrating in baking.

The bean will grow readily in light medium loams of average fertility, provided that such soils are worked up thoroughly into a tilth. Various manurial

trials have been carried out but experiment seems to show that a mixture of 4 : 12 : 4 (N.P.K.) at the rate of about 3 cwt. per acre is the most suitable. Care must be taken, however, that the young seedling roots do not come into close contact with the manure, for in the earlier stages, at least, the haricot bean is very susceptible to manure injury.

The bean should be seeded at a rate of about 45 lbs. per acre in rows 22in. apart with 6in. spacing and sown at a depth of from 1½in. to 3in. Though the beans will respond to cultivation yet it should be remembered that it is shallow rooting, and further, that in cultivation care must be taken not to cover the crowns.

Special machinery has been devised for harvesting the haricot bean in Canada and in U.S.A., but on small areas the beans are hand-pulled when the greater proportion of the pods are mature and just prior to the time when they shatter. After cutting or pulling, the beans in the straw are left to cure for seven days, and then from three to five days to dry in the stack. Beans properly cured and dried can be stored in stacks after being de-podded. This is usually done with grain-thrashers that have been adapted for this purpose. The proportion of grain to straw is usually about 1 : 1. In U.S.A. the average yield is from 10-15 bushels, with a normal average of 20 bushels per acre for pea-beans.

The more commonly occurring diseases are anthracnose, bacterial blight, and mosaic.

In addition to general information about its culture, there is in this bulletin a very full list of varieties that are grown, but it would seem that the more popular are Navy Pea, White Boston and White Marrow.

The production of haricot beans should present little difficulty to growers in this State, and suitable land is available throughout the South-West and Great Southern areas. Our climatic conditions are such that sufficient time for full maturity is possible. In swamp areas, where beans are normally grown, and in the irrigation districts there should be no lack of moisture for late planted crops. The manurial treatment suggested could be supplied by using Special Potato, and No. 4 or E. Brand Potato Manures.

E. T. Morgan.

Contagious Abortion-Free Herds.

The following herds have been declared free from contagious abortion, in accordance with the requirements of the scheme for the certifying of herds abortion-free, and unless otherwise declared the certificate remains in force until the date shown in respect of each herd:—

No.	Owner.	No. of Cattle Tested.	Date of Expiry.
			1941.
1	Agricultural College, Muresk	39	30th September.
2	R. J. & A. J. Marshall, Denmark	22	31st October.
			1942.
3	W. A. Beaney, Mt. Shadforth, Denmark ...	12	4th March.
4	W. J. Deal, Scotsdale, Denmark	17	4th March.
5	Grace H. Burnside, Nornalup	44	24th March.
6	A. J. Allen, Denmark	22	5th May.
7	J. Haire, Scotsdale, Denmark	35	14th May.
8	W. Middleton, Denmark	30	15th May.

Destruction of Emus.

A. ARNOLD, Chief Inspector of Rabbits.

Introduction.

Though primarily associated with the outback areas in a similar manner to the kangaroo, emus are at times seen in large numbers on the fringe of settlements. A few might be found in closer, owing to being driven in along roads, sometimes for miles, by fast moving traffic.

At one time they were kept in check by dingoes, but, with the reduction in numbers of this pest, the birds were able to breed up with less hindrance. Foxes account for some eggs and possibly a few young ones but once in the settled areas emus have no natural enemies, and, being unable to get back owing to fences, can breed without restriction.

They are usually found in bands, and naturally the larger the band the greater the damage done; and the more there are to watch for danger, the harder they are to approach. Few people, outside of those actually affected by a drove of these creatures, realise that the damage they do amounts to thousands of pounds.

As with other migratory birds they follow the seasons, and consequently a dry season in the northern areas of the State, causes them, after the first rains in the wheat-belt, to move down in great numbers towards the farming areas, to return northwards when the summer rains commence there.

In 1936-37, after a long period of dry seasons in the north, they appeared in the unfenced areas north of Northampton and the eastern wheat-belt beyond Merredin, in unprecedented numbers. A bonus was offered for their destruction, resulting in over 72,000 being destroyed.

CONTROL METHODS.

Fencing.

It is interesting to note the effect of efficient rabbit-proof fencing against this pest in this instance, as over 80 per cent. of those slaughtered were killed outside the rabbit-proof fence. Another indicant of this is that numbers of the station fences join on to the rabbit-proof fence, and, at practically every junction, emus will be found in scores in season. If left alone they perish there, but if alarmed or driven, some of their number get through.

As most of the damage done to crops is on unfenced areas the first line of defence would be adequate fencing. Those that succeed in getting through can then be killed if a determined attitude to eradicate them instead of one of tolerance, is shown. The rifle is very effective where they are confined to paddocks by fencing.

Pits and Enclosures.

Emus will patrol along a good fence for days and some settlers have been successful in their eradication by digging pits close by and erecting a wing fence at an angle of 45 degrees from the pit, leaving out a few panels each way. When a flock is noticed moving along the fence the farmer can, by going out on horse-back or in his car, rush them towards the pit where they can be destroyed. Similarly, instead of a pit, suitable enclosures can be erected with wings extending in each direction and the same procedure followed to drive them in. Many such traps as the latter have been erected along the rabbit-proof fence with success.

Except in dry seasons, when they must return for water, emus rarely return to the same place twice. This seemingly haphazard roving makes it particularly difficult to obtain effective results by baiting. Poisoned wheat, placed along the rabbit-proof fence in heaps where it could be easily seen, was tried where the emus continuously travel in hundreds and, although the birds were seen moving along daily, they took very little notice of the bait. This may have been because wheat was a new type of food for them, though it has been reported that it is not uncommon for them to follow about 50 to 100 yards behind a drill picking up the wheat as it is sown.

Poisoning of Food.

Emus, being curious creatures, may be attracted by a piece of rag or a tin tied to a stick, and poisoned wheat placed in cupfuls close to these might be effective. Their roving nature, however, makes this method dependent on their approaching from such a direction as to perceive the attraction. Free feeding for a time where they are liable to come, until they are regularly eating the food put out for them, and then putting down an abundance of poisoned food, would probably decimate, if not entirely eradicate, them. The following recipes are culled from the Department's Bulletin No. 57, Vermin Destruction.

Wheat and Strychnine Bait.—Strychnine (soluble) 1 ounce, brown sugar, 4 lbs., wheat, 20 lbs. Boil the strychnine in 1½ gallons water until dissolved. Add the sugar and dissolve, then pour the solution over the grain in a tub, and allow to stand until the liquor is absorbed. Can be used fresh or dried, as required.

Arsenic and Wheat.—One lb. arsenic, ½ lb. washing soda, 1½ gallons of water, boil until arsenic is dissolved, and pour liquor over 20 lbs. of wheat in a tub and allow to stand until liquor is absorbed. The addition of about 2 lbs. of sugar will make the bait more palatable.

It should be stated that emus are not easily destroyed by poison. Birds of all kinds are less susceptible to poison than animals. The gastric juices of the digestive organs of the latter set strychnine in operation, whereas a bird grinds up its food mill-fashion. Consequently it would take much more strychnine to kill a fowl than a dog.

Unfortunately, there is no one way of controlling the menace, the best way, probably the only way to make an appreciable effect, is by the use of poisoned water, which mode has become the accepted method.

Owing to the drought conditions up north, Killicks and Meggits nuts were frequently fed to sheep, it was mostly done at the mills adjacent to the homesteads, and it was observed that the emus and kangaroos, but particularly the emus, ate the nuts before the sheep had a chance and waited about the mills till the nuts were distributed. Apart from poisoning the water, there would have been an excellent opportunity to have tried poisoning with the ordinary phosphorised pollard rabbit baits which very much resemble Meggits nuts. In this case the emus were forced to come to one particular spot, this was the mill, and they could all have been killed by poisoning the water.

Poisoning of Water.

During the hottest months of the year when natural water supplies are non-existent, and the birds will drink readily, poisoned water is effective. Water placed for them to drink should be in the shade of trees or on the edge of fields where they are known to congregate. Troughs or tins placed for them should be sunk in the ground, as the birds like to sit down while drinking. At first the containers should

be filled with fresh (unpoisoned) water, until it is seen that they are partaking of it readily day after day, and have become accustomed to drinking there. Poison, either strychnine, cyanide, or arsenic, may then be effectively used, recipes for their mixing being as follows:—

Strychnined Water.—Dissolve one ounce of strychnine in one-third pint acetic acid, or quart of vinegar, and add to 12 gallons fresh water. Add 3 or 4 pounds of sugar to counteract the bitter taste of the strychnine and place out in the troughs.

Cyanide and Water.—One lb. of cyanide is sufficient to poison 100 gallons of water. Do not use boiling water to dissolve the cyanide, the fumes given off are poisonous. Dissolve about 2 ozs. cyanide in an ordinary whisky or beer bottle of water, and add to 12 gallons of fresh water. *Note,* that troughs used for cyanided water should be made of black iron or steel: Cyanide reacts with tin or zinc, and in doing so becomes weakened and may fail to kill, do not use new (bright) kerosene or petrol tins or galvanised troughs.

Cyanide, like strychnine, kills quickly, and you see the results, but it is a very unstable poison, and the presence in the water used of some minerals, or acid, causes it to deteriorate rapidly.

Arsenic and Water.—Take 2 lbs. of arsenic (common commercial), one lb. washing soda and 2 gallons of water. Boil for 40 minutes or until the arsenic is dissolved. This stock solution is sufficient to make up 60 gallons of poisoned water. Arsenic is a sure poison, but is slower than either strychnine or cyanide.

Warning.—Children, irresponsible people, also the settlers' own stock, must not be allowed access to any of the abovementioned poisons.

Footrot in Sheep.

L. W. MAHAFFEY.

Assistant Veterinary Pathologist.

In his work on footrot of sheep Dr. W. I. B. Beveridge of the C.S.I.R. McMaster Animal Health Laboratory, in the University of Sydney, has gone so far in solving the many problems of the disease and in describing conditions under which its control may be successfully achieved, that it has been thought desirable to make the information available to the farmer in a condensed form in this Journal.

Definition of the Disease.

The term footrot should only be used for a specific infectious disease of the feet of sheep caused by a micro-organism which has for some time been known as the "K" organism, but which is to be known as *Fusiformis nodosis* (n.sp.) Beveridge*, and not for other diseases of the feet resulting in lameness, having appearances different from those described presently and in which *Fusiformis nodosis* is absent.

**Council of Scientific and Industrial Research* Bulletin (in publication). "Foot-rot in sheep. A Transmissible Disease Due to Infection with *Fusiformis nodosis* (n.sp.). Studies of its Cause, Epidermiology, and Control." By W. I. B. Beveridge.

Cause of the Disease.

The cause of footrot is *Fusiformis nodosis* and the disease will not develop without it despite the presence of other factors such as wet conditions underfoot which can only be called predisposing factors.

Sheep Affected.

All breeds of sheep are susceptible to footrot as are ewes and rams, young sheep and lambs are particularly so, but all age classes may be affected. The causal organism is very specific for sheep and while it is possible that infection may occur in goats it is very unlikely that other animals act as carriers, except mechanically, and this danger is so remote as to constitute a negligible risk. Cattle suffer from a disease referred to as footrot but this is almost certainly due to other causes.

Seasonal Incidence.

The disease is mostly seen when there is a flush of feed and new cases do not appear as a rule during summer. The reason for this is, of course, that the periods during which feed is plentiful are those in which the organism finds conditions most suitable for its spread from sheep to sheep.

Signs of the Disease.

Very often more than one foot is affected. The first sign is "scald" as it is called by the farmer. There is a reddening of the skin between the claws, accompanied by lameness. Later the part becomes moist, a clear fluid is seen to ooze from the skin and a characteristic, very evil odour is present. A very small amount of pus may occur under the horny tissues but separation of the sole of the hoof is of frequent occurrence. Usually pus is not seen in any appreciable quantity, instead there is a small amount of yellowish grey dead material between the separating tissues, the odour of this material is most offensive. The front portion of the wall of the hoof may become separated from the underlying tissue and as there are sensitive structures ("quick") in this region, the lameness may be most acute and the animal will often move about on its knees. There is frequently considerable loss of condition during this period due largely to the pain suffered and the inability to move about and feed normally. Such a stage may be reached in a fortnight although it usually takes longer than this. Should the animal remain for a long period in this condition it is said to be suffering from the chronic form of footrot.

Other Diseased Conditions of the Feet.

It is important to realise that there are other conditions of the feet of sheep which should not be confused with infectious ("contagious") footrot. These are due to different causes and cannot be eradicated in the same way.

Some years ago footrot was said to exist in two forms, the ordinary "sub-acute" form which often developed to the chronic state and a less common "acute" or "malignant" footrot. The former type displayed signs as described above for infectious footrot and is due to *Fusiformis nodosis*; the latter type is caused by a microbe known as *Fusiformis necrophorus* which is commonly present in the alimentary tract and the environment of sheep and other animals. It is proposed to call this latter condition *Digital Suppuration*. The farmer must clearly differentiate between these affections and not regard them as merely different manifestations

of one disease because, where contagious footrot has been eradicated, digital suppuration may occur and the property owner be led to question the efficacy of the recommended and satisfactory measures for the eradication of true contagious footrot. This he can learn to do and it has been suggested that he popularly refer to digital suppuration as foot abscess, because of a similarity to boils in man, with large amounts of pus. The condition is not common but has been encountered in this State and is apparently only widespread when rainfall has been excessive. This is perhaps due to the heavy contamination of the pastures by the organism from the intestines of sheep which are passing more droppings than usual under the influence of the green feed. Generally only one claw of a lame sheep is affected, there is a very definite accumulation of pus under the horn of the claw and at its upper extremity, and moreover, older sheep are most commonly affected. All these points are in definite contra-distinction to infectious footrot. There are still other diseased conditions of the feet but they are quite rare here and need not be mentioned, perhaps at the risk of confusing the reader. Digital suppuration or foot abscess is not controllable by elimination of affected sheep or spelling of pastures. Treatment may be attempted as for footrot after very carefully paring away sufficient horn to allow the antiseptic to reach the pus and dead tissue and for the pus to drain away.

Treatment of Footrot.

A concrete footbath is an absolute necessity on a property where curative treatment for footrot has to be undertaken. This may be built in the shape of a race or pen and the size would be determined by the number of sheep one may have to treat. For most farmers in this State one accommodating 30 to 50 sheep should be suitable. The solution used in the footbath may be either formalin or copper sulphate (bluestone). Formalin is the cheaper and is very effective, it does not stain wool and hardens the affected feet. It is used in a concentration of 2 per cent. Copper sulphate is also very good and is usually employed satisfactorily in 5 per cent. solution which is ½ lb. to the gallon of water. This concentration may be increased up to double, i.e., 10 per cent. All affected animals should be kept isolated in a small paddock or yard as soon as noticed lame. The affected feet must be trimmed thoroughly and all loose separated horn removed. It is quite unreasonable to expect the best results unless the antiseptic used is allowed to come into intimate contact with the diseased tissue; nor are the sheep merely walked hurriedly through the bath, on the contrary they must be held there for at least one hour. Treatment should be repeated three or four times at two-day intervals. The same solution may be used five times before replacing it but the droppings from the sheep, which accumulate during their stay in the bath, should be skimmed off each time after use. If it is possible sheep should be kept on a dry floor for a few hours after standing in the bath. External dressings may be applied instead of, or in conjunction with, the above, but as the footbath treatment meets the requirements in all respects it is not proposed to give formulae for the many which have been used. If, however, treatment of only one or two sheep ever became necessary this could be done with a mixture made by stirring into one quart of warm Stockholm tar, two ounces of finely ground copper sulphate, and finally adding one tablespoon of lysol. The mixture is applied with a brush. Such treatment is not so effective as the bath treatment since, although the feet must first be trimmed and pared down, it is not considered that the antiseptic reaches all the diseased tissue. The use of a footboot in conjunction with the above would considerably enhance its value.

Prevention and Eradication.

In summer and during very dry periods the disease may not be evident at all or at least is not spreading amongst the flock; when seasonal conditions become more suitable for the infective agent fresh outbreaks occur even in the absence of the introduction of new sheep.

How does the responsible infective agent (*Fusiformis nodosis*) survive during such periods? Two means of survival are possible and in order to elaborate a control or eradication scheme, we must know which is the more important and what is the period of each. These are:—

(a) Survival apart from the sheep, that is, on pastures, in sheep yards and the surroundings in general.

(b) Survival in association with the sheep; that is, chronically infected feet.

Experimentally and in actual field trials on a number of farms it has become quite clear that the organism survives for a very brief period indeed apart from sheep. In material kept from footrot cases Beveridge has shown that kept moist or air dried the infective agent survived 24 hours but not four to eight days. When material was mixed with mud survival was three days, rarely one week and never three weeks. In droppings it survived one week but not two. In a muddy yard infected by placing infected sheep in it the causal organisms survived 24 hours in one of three experiments. In six experiments it could not be demonstrated in damp pasture from which infected sheep had been removed from nine hours to two weeks previously. In a series of field trials carried out on infected properties evidence has been produced to justify the conclusion that under the most favourable conditions ever likely to occur the organism could not survive a period of seven days on pastures, in yards, etc. In the dry months this period would be shortened. Allowing for a "safe" margin then, it is considered that 14 days spelling of pastures is an effective period at any time of the year to rid them of the infective agent.

What of the survival of the organism *Fusiformis nodosis* in association with sheep? This has been shown to be of longer possible duration. Beveridge has shown that this infective agent can survive 3½ years in chronically affected sheep. Sheep which have apparently recovered may occasionally harbour the infection for seven months. Sheep recovered for a month or more and showing absolutely no signs of the disease are apparently quite free of infection.

For the eradication of the disease from a property then, it is quite clear that the infected sheep which carry *Fusiformis nodosis* are the source of reinfection and it is to these that great attention must be given to achieve the final desired result of eradication. Upon the detection of these and either their complete cure or elimination from the flock depends the success or failure of one's campaign against the disease.

In order to control and eradicate footrot of sheep the following procedure properly carried out will result in completely satisfactory results. In summer the feet of all sheep on infected properties should be systematically examined. All animals showing any evidence of the disease should either be eliminated or set aside in complete isolation to attempt curative procedures as outlined above. To make the job complete all sheep judged free of hoof abnormalities should be run through a footbath and be returned to the paddocks which have been completely free of sheep for fourteen days. If it is not judged economically possible to dispose of all infected sheep these must be held in isolation undergoing regular treatment until completely cured when they may join a "clean" flock in a clean paddock. All new introductions of sheep (including rams) to such a flock must be free of footrot and should be subjected to the footbath treatment first.

SUMMARY.

(I) Footrot of sheep, using the term in its now accepted correct sense is a specific infectious disease affecting the feet. Without *Fusiformis nodosis* (originally "K") the condition does not occur.

(II) Factors such as particular types of soil, flush clover pastures, dampness under foot cannot lead to the development of footrot without *Fusiformis nodosis* although such conditions may favour the spread of the disease if there are chronic cases in the flock. The above conditions however may lead to the development of digital suppuration (foot abscess) in the absence of footrot "carriers."

(III) Sheep owners should learn to differentiate between "foot abscess" and footrot, two entirely separate conditions.

(IV) When the above recommendations have been complied with, the most important single factor for the elimination of the disease is the ability to detect and remove the chronic carriers. Farmers will probably find that their success or failure will depend on the care which they exercise in this regard, for it is probably the most difficult of the conditions for them to fulfill.

(V) If a pasture which has been carrying infected sheep and is therefore contaminated, is kept free of sheep for two weeks then sheep which are free of the disease may be run on such pastures without development of the disease.

(VI) Flocks which are free from footrot may graze "clean" pastures without developing the disease if precautions are taken to prevent reintroduction of the causal organism.

(VII) Bearing the above factors in mind and acting in accordance with the known facts a flock may be freed of the disease and kept free indefinitely.

A Note on the Determination of the Bushel Weight of Wheat.

I. THOMAS, Superintendent of Wheat Farming and L. W. SAMUEL, Cereal Research Officer.

The results obtained in the determination of the bushel weight of wheat by various methods were compared by obtaining the bushel weight of the wheat using:—

A. The Imperial "Standard" bushel measure as used by the Perth and Fremantle Chambers of Commerce in the determination of the bushel weight of the State's f.a.q. wheat of each season.

B. The Imperial "Drum" bushel measure which is of the same capacity as the "Standard" bushel measure, viz., 8 Imperial gallons, but of different shape, being narrower and deeper than the "Standard" form.

C. The Schopper 1 litre chondrometer (No. 31947) of capacity 0.2205 gallons or 1.764 pints.

D. The Australian Standard chondrometer (No. 186) of capacity 1 pint.

The wheat used in this test was three bushels of graded "Bencubbin." Clean wheat was used to reduce the sampling error.

Both of the bushel measures were weighed on a platform "Asco" scales, the beam of which is graduated to ⅛ lb., enabling the weight to be estimated to 1/16th lb. The Schopper measure was weighed to the nearest gram (1 lb. = 453.6 grams) and the tables supplied with the instrument enable the bushel weight to be determined to 0.1 lb. The beam of the Australian Standard chondrometer is graduated to ¼ lb. and enables determinations by estimation to ⅛ lb.

Five weighings with each method were obtained. The original three bushels of wheat were divided mechanically to an amount sufficient to fill the hopper for the "Drum" bushel measure and the bushel weight determined with this measure. This hopperful of wheat was then used to determine the bushel weight with the "Standard" bushel measure and was then divided mechanically to sufficiently fill the hopper for the Schopper chondrometer. The wheat from the Schopper determination of bushel weight was then used for the Australian Standard chondrometer.

Two separate and distinct samples were obtained from the original three bushels of wheat, the further three samples being obtained by the bulking and interchange of various residues from the mechanical subdivision so that the whole of the three bushels was utilised. The results of the tests are shown in the table hereunder:—

—	Standard Imperial Bushel.	Drum Imperial Bushel.	Schopper 1-litre Chondrometer (No. 31947).	Australian Standard Chondrometer (No. 186).
	lbs.	lbs.	lbs.	lbs.
1	63 5/8	63 9/16	64·5	63½
2	63 9/16	63½	64·6	63½
3	63 7/16	63½	64·8	63½
4	63 7/16	63½	64·6	63⅜
5	63 7/16	63 7/16	64·6	63½
Average ...	63½	63½	64·6	63½

The reproducibility of the results with each instrument is satisfactory. The average bushel weight obtained with methods A, the "Standard" bushel measure, B, the "Drum" bushel measure, and D, the Australian "Standard" chondrometer, are identical. The variations between individual determinations with these three methods are considered to be within the limits of experimental error so that these methods yield the same value for the bushel weight of the wheat.

The calculated bushel weight as determined by the "Schopper" is 1.1 lbs. per bushel greater than that obtained by the other three methods.

Sutton et al state p. 4, that the same bushel weight is obtained with the "Standard" and the "Drum" bushel measures, and that the Schopper chondrometer yields a value 1¼ lbs. greater than that obtained with the "Standard" bushel measure (p. 6).

Literature Cited.

Sutton, G. L.; Teakle, L. J. H.; Thomas, I.; Davenport, N.; Jour. Dept. Agric., Western Australia, Vol. 13 (2nd series), pp. 1-19, March, 1936.

Agricultural Problems.

Agriculturists, pastoralists and primary producers generally, who may be having difficulties of any kind in connection with their production activities, are invited to communicate with the Agricultural Adviser or Veterinary Officer of their district of the Department of Agriculture, when information and advice will be supplied free of charge.

Where identification of plant or stock diseases or insect pests is required, full details of symptoms should be forwarded and also samples of the diseased plant, animal tissue or insect where practicable. Plant tissue intended for examination by the Plant Pathologist should be wrapped in paper and not forwarded in airtight containers, and plant specimens for the Botanist should be pressed between newspaper and dried before despatch. With regard to animal tissue for microscopic examination, this should be forwarded in a solution of 10 per cent. formalin, or if of considerable bulk in a sealed kerosene tin containing a few ounces of formalin as a preservative. Living insects should be sent in suitable containers and dead specimens in methylated spirits.

The addresses and names of Advisers are as follows:—

Albany	A. T. Gulvin (Fruit).
Bridgetown	A. Flintoff (Fruit).
Bunbury	A. F. Flood (Stock Diseases).
Busselton	J. M. Nelson (Dairying).
Denmark	C. W. Tobin (Dairying), B. C. Bignold (Stock Diseases).
Geraldton	N. Davenport, c/o. Government Buildings.
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Margaret River	A. L. Hamilton (Dairying), R. Harley (Stock Diseases).
Metropolitan, Gingin, Chittering	S. E. Bennett (Fruit), c/o. Department of Agriculture, Perth.
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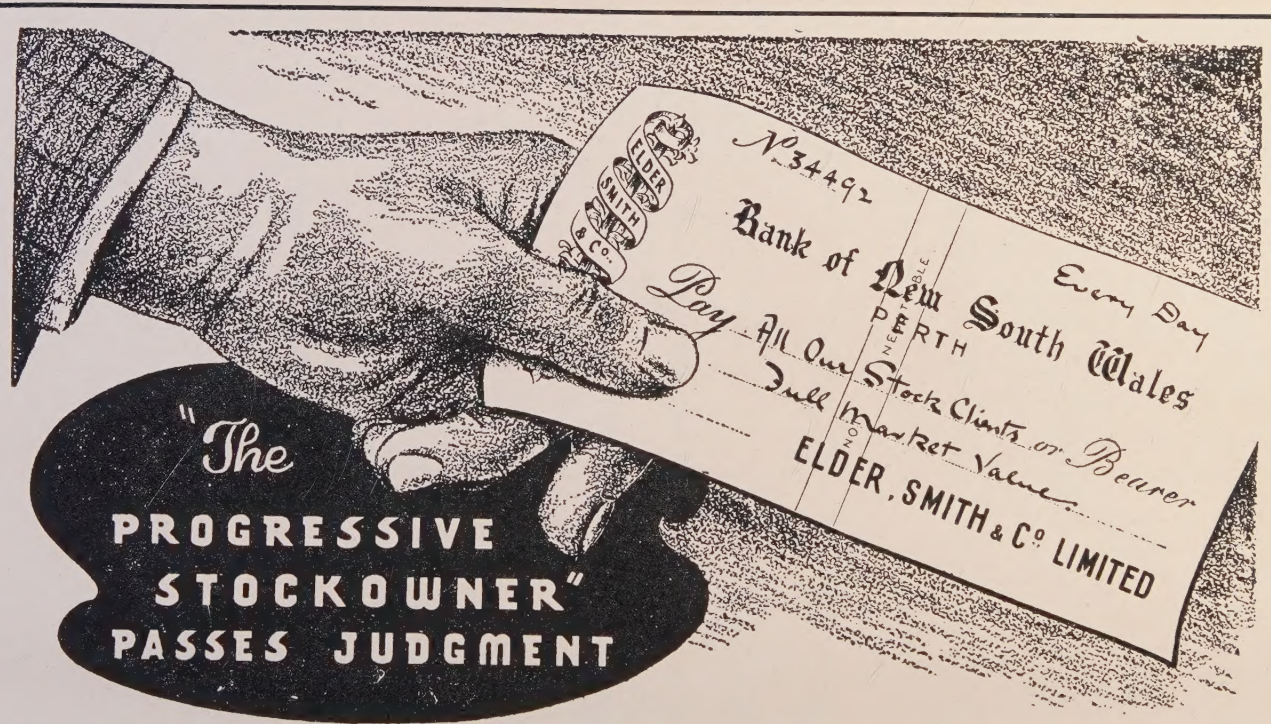

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